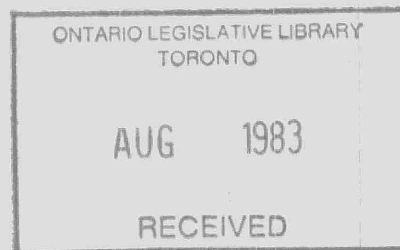


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Sulphur Dioxide (1972) - Heavy Metal (1971) Levels and Vegetative Effects in the Sudbury Area



Ontario

Ministry of the Environment

Hon. J.A.C. Auld
Minister

Everett Biggs
Deputy Minister

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Sulphur Dioxide (1972) - Heavy Metal (1971)
Levels and Vegetation Effects in the Sudbury Area

By

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and

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April, 1973

CONTENTS

- I. Introduction
- II. Sulphur dioxide measurements - 1972
 - (a) Daily
 - (b) Monthly
 - (c) Yearly
- III. Frequency of potentially injurious fumigations - 1972
- IV. Vegetation injury during 1972
 - (a) Sulphur dioxide injury
 - (b) Vegetation injury by other agents
- V. Results of 1971 vegetation and soil sampling program
- VI. Sudbury Special Surveillance 1971
- VII. Snow Sampling program 1972
- VIII. Acknowledgments
- IX. Appendix

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Summary

The Air Management Branch of the Ontario Ministry of the Environment continued to monitor ground level concentrations of sulphur dioxide emitted from the two Sudbury area smelters during the 1972 growing season (May to October). The original monitoring program was set up in 1953 and consisted of 5 monitors. Since 1953 the air sampling network has been expanded and during the 1972 season, the network consisted of 11 **continuous recording SO₂ instruments**.

Sulphur dioxide levels recorded in 1972 at most of the Sudbury area air sampling stations differ considerably from those recorded during previous seasons. This was probably due to a number of factors; however, the main ones are:

1. The International Nickel Co. smelter at Coniston did not operate during the 1972 **growing season**.
2. The pyrrhotite plant at Falconbridge did not operate during the 1972 **growing season**.
3. The Copper Cliff and Falconbridge smelters were shut down for lengthy periods during August.
4. The 1250' stack came into operation at Copper Cliff **late in the 1972 growing season**.

During the 1972 season a total of 72,783 half-hour readings were taken in the Sudbury area. Of this total 16,947 (24%) were SO₂ readings and 55,236 (76%) were zero readings. About 86% of the SO₂ readings were in the range of 0 to 0.04 ppm. Levels in excess of 1.00 ppm were recorded only at the Garson, Skead and Callum stations.

Potentially injurious fumigations were recorded sometime during the season at all stations except Grassy Lake, Burwash, St. Charles and Verner. An area of approximately 50 square miles was exposed to 10 or more potentially injurious fumigations and an area of approximately 1200 square miles was exposed to 1 or more such fumigations.

Vegetation was injured by sulphur dioxide in the Sudbury area during 1972 during the months of May, June, July and September. The total area over which visible injury was observed was approximately 250 square miles. Agricultural crops, trees, vegetables and flowers were injured in amounts ranging from trace to severe.

During the 1970 growing season the Phytotoxicology Section established 15 permanent vegetation and soil sampling plots in the territory affected by the Sudbury area smelters and two control plots

in areas remote from Sudbury. In 1972 a new plot was established at Killarney Park. Samples of vegetation and soil were collected at each of **the** plots at monthly intervals during the 1970, 1971 and 1972 growing season. These samples were analyzed for total sulphur and several metals. The results of the 1970 and 1971 chemical analyses are contained in this report. These results show that there is an area of contamination of the environment by total sulphur, arsenic, iron, and nickel in the Sudbury, Garson, and Skead area. On the basis of the 1970 results, copper may also be elevated. The Kukagami Lake, Rayside, Morgan, Milnet and Burwash area show an intermediate level of contamination.

The levels of total sulphur in the vegetation **were highly** correlated to the amount of SO_2 in the air near the sampling stations as measured on lead peroxide candles **during the years 1970 and 1971.**

The results of the Sudbury surveillance program indicated that, within close proximity of the three smelters, contamination of the vegetation and soil with sulphur and heavy metals was extremely high. Therefore, a Special Surveillance Study was conducted in 1971, with samples collected for chemical analysis from 91 locations.

The results of these analyses show a decreasing level of several elements with increasing distance from each of the smelters. The zone of greatest contamination **occurred within 5 miles of each** smelter.

In early 1972 snow samples for chemical analysis were collected from 30 locations. The results of these analyses indicated that the sulphur levels in the snow were elevated over an area of about 1500 square miles, while about 400 square miles also showed high levels of copper, iron and nickel.

The results for the vegetation, soil, and snow sampling programs give the pattern of contamination prior to April 1972. Since that time, several emission sources have altered their output of SO_2 and other pollutants. The Phytotoxicology Section will maintain its surveillance to monitor the effects of these changes on **the anticipated environmental improvement in the Sudbury area.**

I. Introduction

During the 1972 growing season, (mid May to mid October), the Air Management Branch of the Ministry of the Environment operated a network of 11 instruments in the Sudbury area to measure ground level concentrations of sulphur dioxide. The instruments **were** located (see Fig. 1) at locations where fumes from the smelting operations of the International Nickel Co. Ltd. and Falconbridge Nickel Mines Ltd. have had an adverse effect on vegetation during previous seasons. Sulphur dioxide levels have been measured each season since 1953 at Garson, Skead, Grassy Lake, Lake Penage and Burwash stations. The Kukagami Lake station was established in 1954, the Rayside and St. Charles stations in 1957, the Morgan station in 1961, the Callum station in 1962 and the Verner station in 1972. This report summarizes the data collected at these stations during the 1972 season and compares **them with the data collected during previous seasons.**

A detailed surveillance program was carried out during 1972 to determine the occurrence and degree of vegetation injury. A month by month record of all vegetation damage is included in this report.

The results of the chemical analysis of the vegetation, soil and snow samples which the Phytotoxicology Section, Air Management Branch, have been taking in the Sudbury area are also reported in this report.

II. Sulphur dioxide measurements - 1972

(a) Daily measurements

Sulphur dioxide data collected at most of the stations differ considerably from **those** collected at the particular stations during previous seasons. This is probably due to a number of factors; however the major factors are:

1. The International Nickel Smelter at Coniston did not operate during the 1972 **growing season.**
2. The pyrrhotite plant at Falconbridge did not operate during the 1972 **growing season.**
3. Both smelters were shut down for lengthy periods in August.
4. The 1250' super stack at Copper Cliff came into operation late in the 1972 **growing season.**

During the 1972 season valid data was collected at six of the stations for over 90% of the time (see fig. 2) and at 10 of the stations for over 80% of the time. St. Charles was the only station which had valid data for less than 70% of the season.

In seasons previous to 1972 sulphur dioxide was generally recorded in the Sudbury area between 10 and 15% of the time. In 1972, SO₂ was recorded 24% of the time. Approximately 86% of the half-hour SO₂ readings were in the range of 0-.04 ppm. The reason for the large number of low concentration readings is that part of the air monitoring network was made up of Davis SO₂ analysers. The Davis instrument is a very accurate low range instrument that measures low level concentrations which a Thomas autometer would not record. At stations such as Burwash and Morgan, where Thomas autometers were operated, there was no marked increase in the number of low level concentrations recorded. During the entire 1972 season a total of 72,783 half-hour readings were taken at the 11 Sudbury area air sampling stations. Of this total, 16,947 (24%) were SO₂ readings and 55,236 (76%) were zero readings.

In the following table, the number of days the air sampling stations were operated as well as the number of days on which some level of SO₂ was recorded and the maximum half-hour concentration are shown:

Station	No. of operative days	No. of days SO ₂ recorded	Maximum $\frac{1}{2}$ hour concentration ppm	Date
Garson	183	90	1.99	July 16
Skead	184	125	1.34	May 26
Kukagami Lake	153	119	0.71	June 18
Grassy Lake	122	96	0.32	July 18
Lake Penage	184	135	0.84	May 18
Morgan	184	25	0.70	June 28
Burwash	184	31	0.40	September 22
Rayside	184	45	0.84	May 26
St. Charles	122	111	0.18	June 11
Callum	173	130	1.37	May 27
Verner	174	121	0.58	May 12

Some level of SO₂ was recorded on over 50% of the operative days during 1972. Half-hour concentrations in excess of 1.00 ppm were recorded at 3 of the stations. Concentrations in excess of 0.50 were recorded at 8 stations during the season and only one station, St. Charles, did not exceed the 0.25 ppm level.

(b) Monthly Measurements

During the 1972 season concentrations of SO₂ in excess of 1.00 ppm were recorded at the Garson, Skead and Callum air sampling stations. The 1.00 ppm level was exceeded at Garson in May and July (see Tables 1&2), at Skead in May, July and October, and at Callum in May.

Concentrations of sulphur dioxide in excess of 0.50 ppm were recorded during 1972 at all the stations but Grassy Lake, Burwash and St. Charles. The 0.50 ppm level was exceeded every month of the season at the Skead station and during the months of May, June and July at the Garson and Rayside stations. During May concentrations of SO₂ in excess of 0.50 ppm were recorded at Lake Penage, Callum and Verner. During June, the 0.50 ppm was exceeded at Kukagami Lake, Morgan and Callum. The 0.50 ppm was exceeded during July at Kukagami Lake, Lake Penage, Morgan and Rayside stations. There was one half-hour concentration of SO₂ above 0.50 ppm in September at Kukagami Lake.

Concentrations of sulphur dioxide above 0.25 ppm were recorded each month of the season at the Skead and Callum stations and every month of the season except August at the Kukagami Lake, Lake Penage and Rayside stations. The 0.25 ppm level was exceeded in May and September at the Verner and Burwash stations. The St. Charles station was the only one of the 11 stations where the 0.25 ppm level was not exceeded during the season. At Grassy Lake there were two half-hour concentrations above 0.25 ppm and both these occurred in July.

(c) Yearly Measurements

In table 3 of this report, the data collected during the 1972 season **are** compared to **those** collected during previous seasons. Sulphur dioxide was recorded at record high frequencies at the Kukagami Lake, Grassy Lake, Penage, St. Charles and Callum stations. Davis SO₂ analysers were operated at these stations for the first time during 1972. The Davis instrument is an extremely sensitive, low range instrument which records trace levels of SO₂ which the Thomas autometer would not record. About 85% of the SO₂ readings recorded at the 11 Sudbury area stations were in the 0 to 0.04 ppm range.

While the frequency of SO₂ fumigations was higher at several stations during 1972 than previous years, the frequency of SO₂ concentrations above 0.25 ppm was considerably lower than in previous years. Sulphur dioxide concentrations above 0.25 ppm were recorded 2.75% of the time at the Skead station during 1972 and this is a record low for this station. St. Charles was the only station where concentrations above 0.25 ppm were not recorded during 1972.

Half-hour concentrations of sulphur dioxide above 1.00 ppm were recorded at the Garson, Skead and Callum stations during 1972. The maximum concentration for the season was 1.99 and this occurred at the Garson station on July 16. The maximum half-hour concentration ever recorded in the Sudbury area was 3.64 and this occurred at the Skead station in 1956. Record low **maximum levels of SO₂ were recorded at** Burwash (0.40 ppm), Rayside (0.84 ppm) and St. Charles (0.18 ppm) during 1972.

III. Potentially injurious fumigations

Field observations made in the Sudbury area over the last 20 years indicate that visible injury on vegetation often occurs when the following daytime concentrations of SO₂ are **exceeded** for the following time periods:

0.95 ppm for 1 hour
or 0.55 ppm for 2 hours
or 0.35 ppm for 4 hours
or 0.25 ppm for 8 hours

For convenience, the factor of 100 has been assigned to any one of the above combinations of concentrations and durations. By assigning a factor to each fumigation, it is possible to compare the fumigations recorded at one station to those recorded at another station and to compare the fumigations recorded at a particular station on a year to year basis.

It should be pointed out that a fumigation with an intensity of 100 will not always cause vegetation injury. Plants vary greatly in their susceptibility to SO₂. White birch, white pine and trembling aspen are considered to be three of the more sensitive tree species while white spruce and red oak are considered to be quite resistant. Buckwheat, barley and alfalfa are some of the more sensitive agricultural crops. The time of the season when the SO₂ fumigations occur also influences the amount of vegetation injury resulting from a particular fumigation. In general, during June, July and August when the photosynthetic rate in vegetation is relatively high, most of the vegetation injury occurs. Later in the season when plant growth rate is relatively low, injury is not common. Frequently during the months of September and October, potentially injurious fumigations may occur but cause little or no injury even to the sensitive plant species.

During the 1972 season 27 potentially injurious fumigations were recorded at the 11 Sudbury area sampling stations (see Table 4). Thirteen were recorded at Skead, 6 at Garson, 3 at Rayside, 2 at Callum and one each at Kukagami Lake, Lake Penage and Morgan. No Potentially

injurious fumigations were recorded at Grassy Lake, Burwash, St. Charles or Verner.

Most of the potentially injurious fumigations were recorded during the first half of the 1972 season. There were 8 in May, 9 in June, and 6 in July. Only one potentially injurious fumigation was recorded in each of the months of August and September and 2 were recorded in October. The four potentially injurious fumigations which occurred during August, September and October all occurred at the Skead station.

During the 1972 season an area of approximately 50 square miles was subjected to 10 or more potentially injurious fumigations and an area of approximately 1,200 square miles was subjected to 1 or more (see fig. 3). During previous seasons much larger areas have been exposed to potentially injurious fumigations. In the table below, the figures for the 1972 season are compared to those for the 1969, 1970 and 1971 seasons.

<u>Year</u>	<u>Area in square miles subjected to</u>		
	One or more Potentially Injurious Fumigations	10 or more Potentially Injurious Fumigations	20 or more Potentially Injurious Fumigations
1969*	1335	75	0
1970	1710	453	44
1971	1950	380	75
1972	1200	50	0

* Strike year

IV. Vegetation injury during 1972

(a) Injury by sulphur dioxide

During 1972 the Phytotoxicology Section, Air Management Branch, conducted a detailed surveillance program in the Sudbury area to determine the incidence and extent of vegetation injury by SO₂. In previous years injury has been reported at distances of as much as 60 miles from Sudbury. During 1972 the maximum distance at which injury was noted was about 15 miles. Almost all the injury by SO₂ during 1972 occurred in May, June and July. In previous years injury has occurred in August and September as well as May, June and July.

Fumigations of SO₂ on May 20, 21 and 22 caused severe injury to vegetables, trees, flowers and lawns in an area directly south of Falconbridge. The injury was confined to the vegetation over about a

two square mile area. Much of the area immediately south of Falconbridge is devoid of vegetation so it is possible that a larger area was exposed to potentially injurious fumigations on these three days. During the last week of May 1972, trace to severe SO₂ injury occurred on white birch and trembling aspen over about a 5 - 10 square mile area in Waters Township about 6 - 8 miles southwest of Sudbury. Thus, during May 1972 three fumigations caused vegetation injury over about a 10 to 15 square mile area.

June of 1972 was an abnormally cold month with above average rainfall. Such conditions would not be conducive to vegetation injury by SO₂. Only four fumigations occurred during the month which caused injury to vegetation. One fumigation occurred on June 12 and caused trace injury on white birch over a two to three square mile area in the Skead area. Severe SO₂ injury (more than 35% of the leaf area affected) occurred on white birch, trembling aspen, red oak, alder, willow, red maple, bunch berry and fireweed over about a two square mile area, directly south of Falconbridge during the first week of June. On June 17, 1972 a fumigation of SO₂ occurred in the City of Sudbury which caused trace to moderate (16 - 35% of leaf area affected) injury on vegetables, flowers and trees. The injury was confined to about a 2 block area in the west end of the city. A fumigation of SO₂ the last week in June caused light injury on oats and timothy in Rayside Township (approximately 10 miles northwest of Sudbury). Severe injury occurred on trembling aspen in this area as a result of the fumigation which occurred late in June.

More vegetation injury by SO₂ occurred during July of 1972 than any other month of the season. Several fumigations occurred during the month which caused trace to severe injury to a number of plant species over about a 250 square mile area around Sudbury. About the middle of July a fumigation occurred in an area about 10 miles north of Sudbury which caused severe injury to trees, vegetables and ornamentals. The total area affected by this fumigation was about 5 square miles. A fumigation on July 16 caused severe injury to vegetables, flowers and trees in the Naughton area. Another fumigation on this day caused severe injury to trees, grass and flowers in an area about 5 miles northeast of Sudbury. Also on July 16, vegetation in the Garson area was severely damaged by an eight hour fumigation which had a maximum half-hour concentration of 1.99 ppm. White birch, trembling aspen, willow and Carolina poplar were the tree species which were injured the most by this fumigation.

While the most severe injury occurred at a location about 5 miles northeast of Sudbury, injury to sensitive species did occur over an area stretching from Garson to the northeast corner of the city of Sudbury. An area of approximately 10 square miles was affected by this fumigation.

Agricultural crops such as buckwheat, oats, barley, timothy and red clover were injured in Rayside and Balfour Townships by three separate fumigations during the last two weeks in July. Most of this injury was light in nature and affected crops to some extent over about a 25 square mile area. Trees such as white birch, trembling aspen and white pine were injured in amounts ranging from trace to light by these three fumigations.

During the month of August, 1972, both the Sudbury area smelters were shut down for a large portion of the month. No vegetation injury by SO₂ was noted during the entire month of August, 1972. In previous years, with the exception of strike years, vegetation injury by SO₂ has been common during August in the Sudbury area.

The only visible SO₂ injury noted during September of 1972 was on a few trembling aspen in Rayside Township. The injury was confined to about a one square mile area and trembling aspen was the only plant species affected.

Complaints of vegetation injury by air pollution - 1972

During the 1972 season the Phytotoxicology Section, Air Management Branch, received and investigated 31 complaints of vegetation injury by air pollution in the Sudbury area. Approximately 75% of the complaints were diagnosed as injury caused by sulphur dioxide and the remainder as injury by other agents. After the results of the investigations were available, a report was sent to the complainant and the alleged source. About 33% of the complaints pertained to injury to agricultural crops and the remainder involved injury to lawns, gardens, ornamental plants and trees.

Most of the complaints were received during May, June and July. Only two complaints were received during August, and both of these were to report injury which had occurred earlier in the season. The operations of both International Nickel and Falconbridge Nickel Mines were shut down for a large portion of August and this was probably why an abnormally low number of complaints of injury were received at that time. A few complaints were received during September and October, however, in most cases these involved injury caused by agents other than air pollutants.

The majority of the complaints were received from residents in an area within a radius of about 15 miles from Sudbury, with 20% of these complaints being registered by residents within the city of Sudbury. Complaints were received from as far away as North Bay and Little Current, however, the vegetation injury in these cases was caused by agents other than air pollutants.

(b) Vegetation injury by other agents

An integral part of the air pollution effects surveillance program is to determine the extent of other endemic problems. A number of physiogenic, pathological, or insect-caused abnormalities have been recorded in the area which is also affected by air pollutants from the Sudbury smelters. Pollutants affect the degree and extent of these other types of injuries, either through a direct effect upon the pathogen or insect population, or through an indirect effect on the host or other indirectly related ecological factors such as soil temperature, water relations, erosion, or lack of available nutrients. Therefore, the pathological conditions noted below usually occur at least five miles from each of the smelters. Some of the most commonly encountered problems are described in this section.

Physiogenic Diseases

Winter Drying

In the spring of 1972 a large percentage of the coniferous trees or stands in Northern Ontario suffered from winter drying. The needles of these trees turn brown as a result of water loss brought on by the warm spring sun and cool breezes.

Salt Damage

Combined with winter drying, foliage on many roadside trees also suffered from salt-spray injury, above the snow surface. Foliage remained green below the snow surface, but was dry and brown above this line. Upon chemical analysis, the brown needles were found to contain up to 10 times the amount of chloride found in the green needles on the same trees or in needles from trees not subjected to a highway environment.

Frost

In June and early July, late frost caused extensive injury to the young succulent foliage of the hardwood trees in the Sudbury area. Close examination of the affected tissue was required to distinguish frost injury from SO₂ damage.

Fungal Diseases

The following chart lists the most common fungal diseases which occur in this area.

<u>Name of Disease</u>	<u>Causal Organism</u>	<u>Host</u>	<u>Type of Injury</u>	<u>Extent of Occurrence (1972)</u>
White Pine Blister Rust	<u>Cronartium</u> <u>ribicola</u>	White Pine	Stem cankers, needle browning, crown dieback	moderate
Sweet Fern Blister Rust	<u>Cronartium</u> <u>comptoniae</u>	Jack Pine	Stem and twig cankers	light
Dutch Elm Disease	<u>Ceratocystis</u> <u>ulmi</u>	White Elm	Crown dieback	severe
Needle Cast	<u>Lophodermium</u> <u>pinastri</u>	Jack Pine	Needle browning and loss of needles	light
Anthracnose	<u>Gloeosporium</u> <u>apocryptum</u>	Red Maple	Leaf spot	moderate
Scab and Black Canker	<u>Fusicladium</u> <u>saliciperdatum</u> <u>Physalospora</u> <u>miyabeana</u>	Peach-Leaf Willow	Blackening of leaves and twig canker and dieback	light
Ink Spot	<u>Sclerotinia</u> <u>whetzelii</u>	Trembling Aspen	Black leaf spots	light
Stem Cankers	<u>Hypoxylon pruinatum</u> <u>Cytospora chrysosperma</u>	Aspen and Poplar	Stem cankers	moderate

Insects

In the Sudbury area the **Birch** Skeletonizer (Bucculatrix canadensisella) caused extensive injury to white birch in late August resulting in foliar browning and early leaf fall. Earlier in the summer, a moderate infestation of Birch Leaf Miner (Fenusa pusilla) caused limited injury to white birch leaves.

Feeding by the larvae of the Large Aspen Tortrix (Choristoneura conflictana) caused light to moderate injury to natural trembling aspen stands in the Sudbury area.

Spruce budworm (Choristoneura fumiferana) and Jack Pine Budworm (Choristoneura pinus pinus) continued to cause injury to balsam fir and jack pine respectively in isolated areas in the Sudbury region during 1972.

Vegetation abnormalities will continue to be recorded as part of the 1973 air pollution surveillance program in the Sudbury area since a full understanding of the forest problems is necessary in this fume damage area in order to properly evaluate the effects of air pollutants on the forest ecosystems.

V. Results of 1971 Vegetation and Soil Sampling Program

During the 1970 growing season the Phytotoxicology Section of the Air Management Branch established 15 permanent vegetation and soil sampling plots in the territory affected by the Sudbury area smelters and two control plots in areas remote from Sudbury. In 1972 a new plot was established at Killarney Park. These plots are located as follows:

<u>Plot</u>	<u>*Distance and Direction from Sudbury</u>
Blind River	100 miles W control plot
Mattawa	110 miles E control plot
Sudbury	Laurentian University
Garson	3 miles NE
Skead	16 miles NE
Kukagami Lake	26 miles NE
Grassy Lake	40 miles NE
Timagami	50 miles NE
Rayside	10 miles NW
Morgan	15 miles NW
Milnet	23 miles N
Callum	18 miles E
St. Charles	30 miles SE
Sturgeon Falls	48 miles E
Burwash	17 miles S
Nairn Centre	30 miles SW
Penage	23 miles SW
Killarney Park	40 miles SW

At each station, the current and one-year old needles of jack pine, and the leaves from trembling aspen, white birch, bracken fern, and forage, as well as soil (0-4"), were collected in June, July, August, and September of 1970. These samples were analyzed for total sulphur, fluoride, arsenic, cobalt, copper, iron, nickel, selenium, and zinc. Repeat samples were collected in June, July, and August of 1971 and 1972. These samples were similarly analyzed, except that fluoride **was deleted from the list.**

At the time of writing this report the full analysis of the 1972 samples was not yet complete. However the 1970 and 1971 data have been compiled and subjected to statistical analysis. Table 5 shows the average concentrations of the various elements in the different species and soil for the 1970 and 1971 collections. Those values for the fifteen surveillance plots which differ markedly from the control plots have been underlined to set them apart from the other figures.

* for plot locations see Fig. 4

The Table of analysis of variance (Table 6 ; F-Values) shows that for most elements in the 1970 collection and all elements in the 1971 collection, the concentrations of these elements vary significantly from species to species, at the 1% level. This indicates that the levels of a given element in a single species are not necessarily comparable to the levels of that element in another species. For all elements except arsenic (1971 and 1972) and copper (1972 only) the levels of the various elements vary significantly from station to station at the 1% or 5% level. In most cases Sudbury, Garson, and Skead were the three stations which were significantly higher than the others. From Table 6 the following trends **were** apparent:

1. The 1971 results give a similar picture to **those** outlined for the 1970 results. The major changes appear to be that copper levels have been reduced and the iron levels have increased from 1970 to 1971.
2. The levels of cobalt and zinc vary randomly, well within the normal limits for all species and stations.
3. Elevated sulphur levels predominate at Sudbury, Garson, Skead, and Kukagami Lake, with lower levels recorded at Rayside, Morgan, Milnet, and Burwash. Sulphur levels **were** not consistently high at the remainder of the stations.
4. Arsenic levels **were** consistently elevated at Sudbury, Garson, and Skead.
5. The copper levels **were** reduced from 1970 to 1971. Only at isolated locations do the levels of copper appear to be elevated.
6. The iron levels **were** elevated for many stations for all species and soil.
7. The nickel levels **were** consistently elevated at Sudbury, Garson, Skead, Kukagami, Rayside and Callum.

These results show that there is an area of contamination of the environment by total sulphur, arsenic, iron, and nickel in the Sudbury-Garson-Skead area. On the basis of the 1970 results, copper may also be elevated. The Kukagami Lake, Rayside, Morgan, Milnet, and Burwash areas show an intermediate level of contamination.

The elevated levels of total sulphur in the vegetation have been closely related to atmospheric sulphur levels. The sulphation rate measured on lead peroxide candles near several of the vegetation plots is highly correlated to the total sulphur levels in vegetation collected at these plots in 1970 and 1971 (Table 7 and Figs. 5 & 6). For these calculations the total sulphur values for all of the vegetation samples for each station were combined. When plotted against the sulphation rates, the regression equations and correlation coefficients were determined. The correlation coefficient (r) for 1970 was 0.73 and for 1971, 0.96. These values are statistically significant at the 5% and 1% level respectively.

VI. Sudbury Special Surveillance (August 1971)

The results of the Sudbury surveillance program, as well as the work of other investigators, indicated that, within close proximity of the three smelters, contamination of the vegetation and soil with sulphur and heavy metals was extremely high. Therefore, a Special Surveillance Study was conducted in 1971 with samples collected from 91 locations; using the Copper Cliff, Coniston and Falconbridge smelters as the reference points. Samples were collected at one-half mile and then at frequent intervals out to twenty-five miles in several directions from each of the smelters. At each location the following samples were collected, if available: trembling aspen, forage, soil (0-1") and soil (4-6"). These samples were analyzed for total sulphur, arsenic, cobalt, copper, iron, nickel, and zinc.

Table 8 shows a partial list of the results of the chemical analysis. These results reveal that within 5 miles of the three smelters there is an intense zone of contamination of vegetation and soil by sulphur, copper, iron, and nickel. In some areas, contamination by arsenic also appears to be a possibility. Between 5 and 10 miles there is some reduction in the level of contamination and from 10 to 20 or 25 miles there is a major decrease in the levels of the named elements (see map-Fig. 7). Contamination of the soil and vegetation by cobalt and zinc does not appear to be a problem.

VII. Snow Sampling Program 1972

Both the regular surveillance and the special surveillance studies described above indicate elevated levels of sulphur, copper, iron, and nickel for soil and vegetation at many of the sampling locations. Since the build-up of these elements in the soil has taken place over several years, some estimate appeared to be required, to illustrate the amount presently being added to the environment at these localities. Therefore, a snow sampling program was instituted in an attempt to determine the short-term build-up of sulphur and several metals in an area extending up to 50 miles in several directions from Sudbury.

In January 1972, thirty snow sampling locations were established according to the following criteria:

1. the site should be at least 100 yards from a major roadway.
2. the site should not be affected by local sources of pollution, other than the source in question.
3. the site should be an open area to allow for free fall and accumulation of the snow, however the site should not be so exposed as to be subject to blowing or drifting snow.

Sampling sites were established at the following locations:

<u>Location</u> (see Fig. 8)	<u>Distance and direction from the City of Sudbury</u>
Blind River	100 miles west (control plot)
Mattawa	100 miles east (control plot)
Laurentian University	within city limits
Ash Street	within city limits
New Sudbury (LaSalle Bld.)	within city limits
Cinnottiville	4 miles southwest
Naughton	11 miles southwest
Lake Penage	23 miles southwest
Nairn	30 miles southwest
Massey	60 miles southwest
Garson	3 miles northeast
Skead	16 miles northeast
Timagami	56 miles northeast
Coniston	8 miles east
Callum	18 miles east
Hagar	28 miles east
Sturgeon Falls	48 miles east
North Bay (1)	85 miles east
North Bay (2)	85 miles east
St. Charles	30 miles southeast
Happy Valley	14 miles northeast
Hanmer	12 miles north
Capreol	15 miles north
Milnet	23 miles north

<u>Location</u>	<u>Distance and direction from the City of Sudbury</u>
Rayside	10 miles northwest
Morgan	15 miles northwest
Burwash	17 miles south
Killarney Rd. and Hyway 69	20 miles south
Tyson Lake	28 miles southwest
Killarney Park	40 miles southwest

At any one location, the snow was collected using five 32 oz. plastic bottles (3 in. diam. x 8 in. length). The bottles were inverted and then inserted into the snow randomly at each site. The bottles were then removed from the snow, covered with a plastic bag and transported to the laboratory.

The samples were allowed to melt overnight at room temperature and then the five portions from each location were combined. The total volume of the sample was measured along with the pH. One-half of the sample was acidified to keep the metal ions from plating out on the plastic. This portion of the sample was analyzed for its metallic components. The non-acidified portion was analyzed for the sulphur it contains.

Collections were made in January, February, and April. The January and February collections followed a major snowfall in the area. Any snow which appeared to have fallen between the time of the major snowfall and the time of collection was not included in the sample. The April collection was carried out at a time when the snow was receding. In fact all **April** samples were "snow-ice", indicating that a thaw-freeze situation existed before the time of sampling.

The samples were analyzed for total sulphur, cadmium, chloride, cobalt, copper, iron, nickel, and zinc as well as pH.

Results (see Tables 9 & 10)

1. The results for cadmium, cobalt, and zinc were all uniform and low.
2. The majority of pH **were in the region of 4.0 to 5.0**, even for the control samples (**Table 10**).
3. Except for iron, the majority of the readings for the April samples **were** markedly lower than those of the previous collections.

4. The levels of all elements, except chloride, **decreased with** increasing distance **from** Sudbury.
5. In the intensively affected zone (~~see~~ map) the levels of the various elements **were** markedly higher than the controls:

Sulphur	2-5)	
Copper	10-150)	times greater than the
Iron	2-50)	control samples.
Nickel	10-100)	

Discussion of Snow Results

The pH for the majority of the snow samples, regardless of the distance from Sudbury, was between 4 and 5, irrespective of the sulphur content. It appears that the snow lacks a high buffer capacity resulting in a lower pH despite the fact that the original H-ion concentration may not have been high. Therefore, unless the buffer capacity of the soil is capable of raising the pH, the melt-water remains acid as it enters the water-table, lake or stream.

The fact that the April levels were lower than those for January and February indicates that as soon as the thaw begins, the metals, being loosely bound, must be removed in the run-off water. Whether the sulphur is lost as an ion in the water or re-emitted as a gas is presently being studied at Laurentian University under a grant from the Air Management Branch. Another important factor which must be considered then, is the fact that possibly some of the trapped sulphur is re-emitted during thawing of the samples in the laboratory. If this is the case, the sulphur levels found during the analysis would be lower than those actually present in the sample at the time of collection.

The various chloride levels are indicative of local situations, not necessarily related to the smelter operations. These results show that a few of the sampling locations will have to be further removed from a highway environment, compared to their present location. The elevated levels of chloride at most stations show that the salt being applied to roads is being carried considerable distances in salt-laden sprays whipped up by vehicular traffic.

These results show that during January and February of 1972, elevated levels of total sulphur were found in snow samples collected in the Sudbury area. About 1500 sq. miles appear to be affected in this manner. About 400 sq. miles in and around Sudbury also showed high levels of copper, iron, and nickel in the same snow samples collected during this period.

The high levels of sulphur, copper, iron, and nickel for this area show that the snow is acting as a sink for these elements and that in the spring they become deposited in the soil or are carried away in the run-off water. These results also show that, before the opening of the new stack at Copper Cliff, rather large amounts of these elements were being deposited in very short periods of time. It is estimated that the samples were not on the ground more than 10 days from the time of fall to the time of collection. Taking into consideration the number of square miles affected, the several feet of snow which fall each year, and the length of the winter, the snow represents a very large storehouse of sulphur and heavy metals, all of which are released into the soil and water systems at the time of break-up.

Conclusions of vegetation, soil and snow sampling program

The foregoing results give a clear pattern of the area of contamination as a result of the Sudbury smelter operations as they existed before April 1972. Since that time, the super stack (1250') at Inco has become operative, while the Coniston smelter and the pyrrhotite plant at Falconbridge have ceased operations. In addition, the iron ore plant at Copper Cliff is to reduce its emissions of SO₂ to 250 tons/day during the 1973 growing season. Continued close surveillance by the Phytotoxicology Section will reveal the effect of these abatement measures on reducing environmental contamination in the Sudbury area.

VIII. Acknowledgments

The writers wish to express their gratitude to Dr. S.N. Linzon, Chief of the Phytotoxicology Section, Air Management Branch, for his advice and supervision; to Mr. Ken Waldie and Mr. D. Neve for maintaining the SO₂ monitors; to Mr. D. Ogner for compiling the SO₂ data; to Mr. B. Chai for statistical analysis of the data; to Mr. A. Rayner and Mr. Ron Wills and the staff of the Air Laboratory for analysis of samples and to Mrs. J. Springer for secretarial assistance. The contribution and cooperation of these people have made possible the presentation of this report.

IX. APPENDIX

Fig. 1 SO₂ monitoring stations in the Sudbury area

- ⊕ Smelter
- SO₂ Monitor

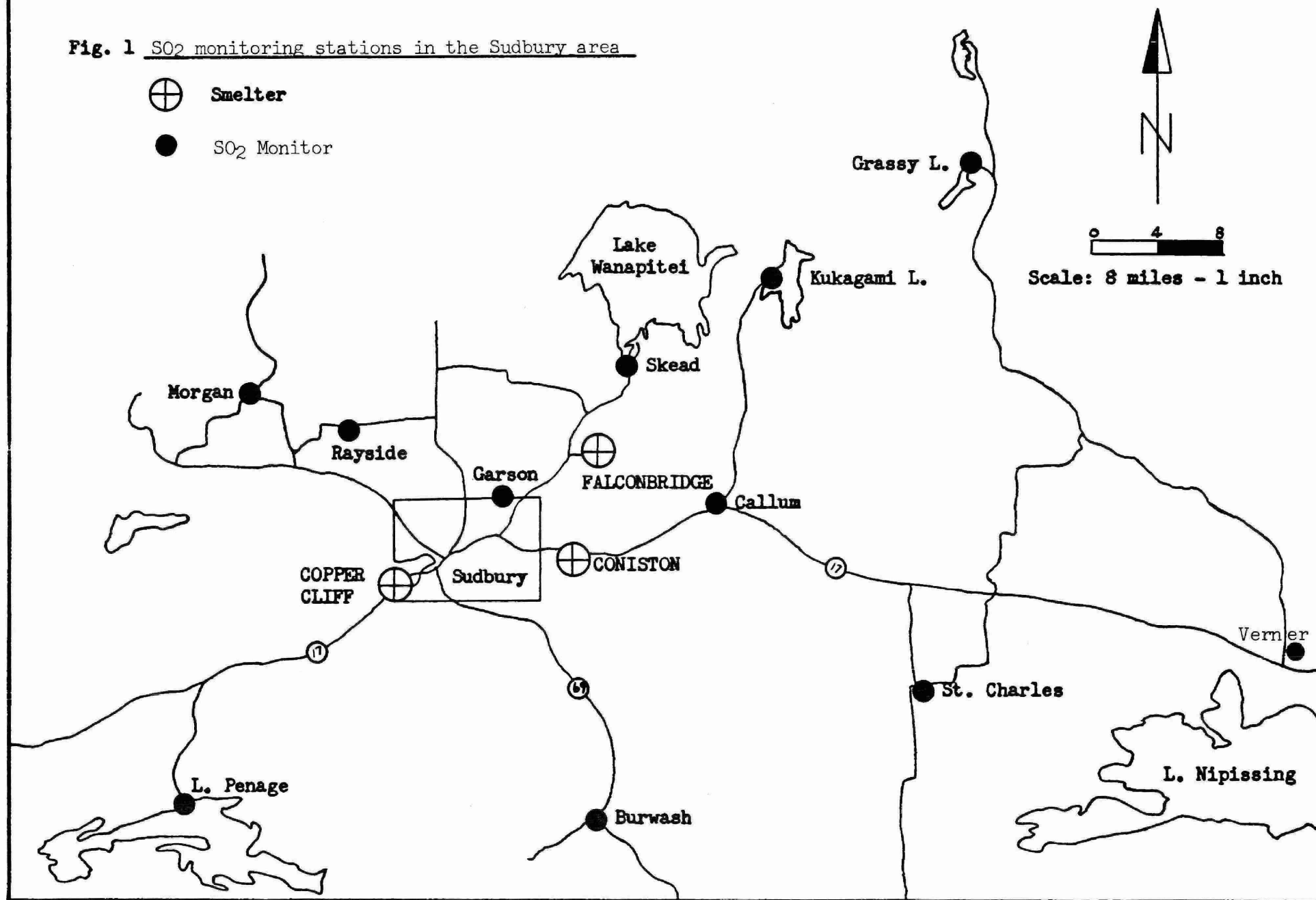


Fig. 2. Operative Record of Sudbury Area SO₂ Sampling Stations During the 1972 Season

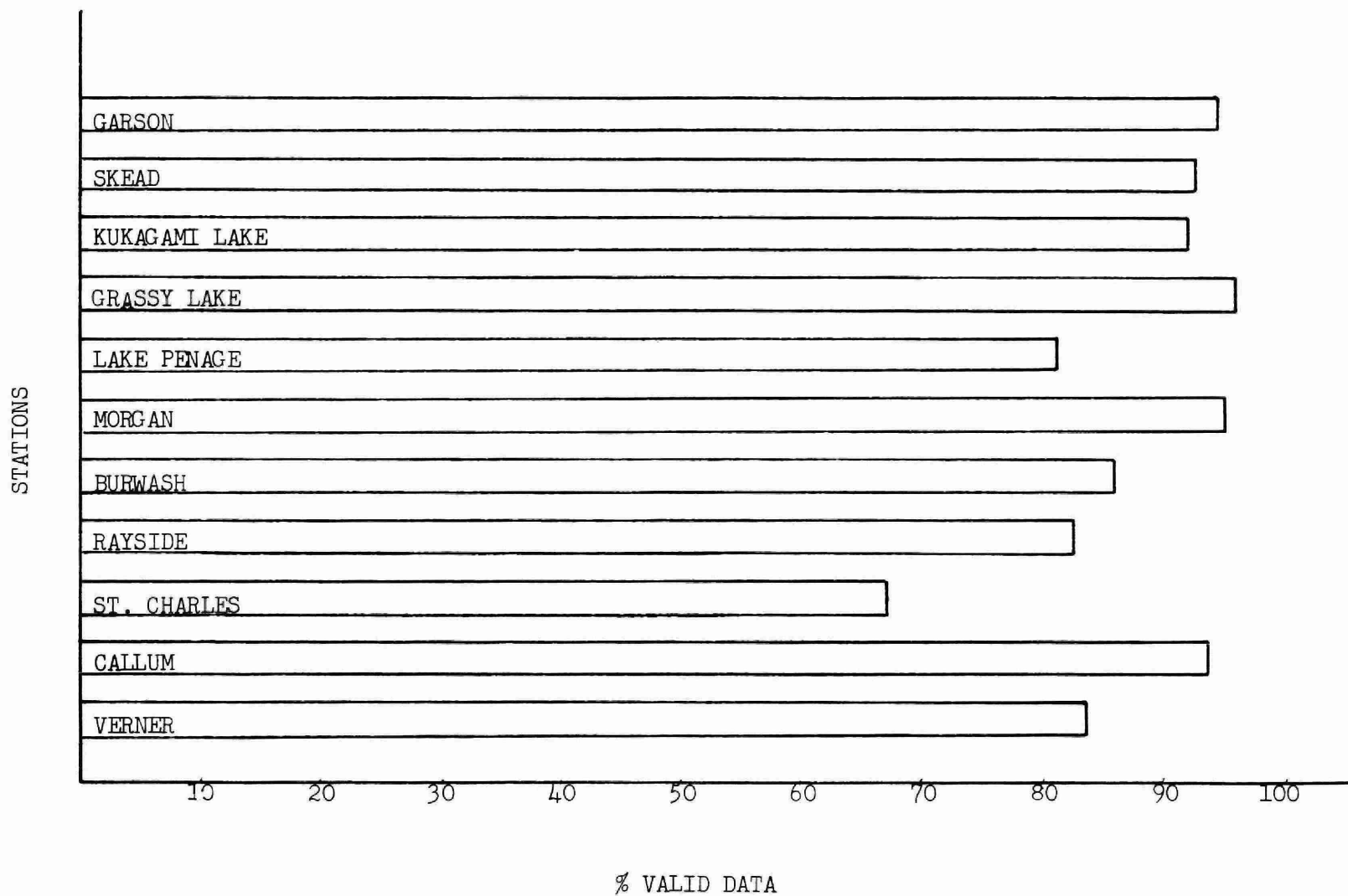


Fig. 3. Approximate areas subjected to 1 and 10 potentially injurious fumigations during the 1972 season

 1 or more

 10 or more

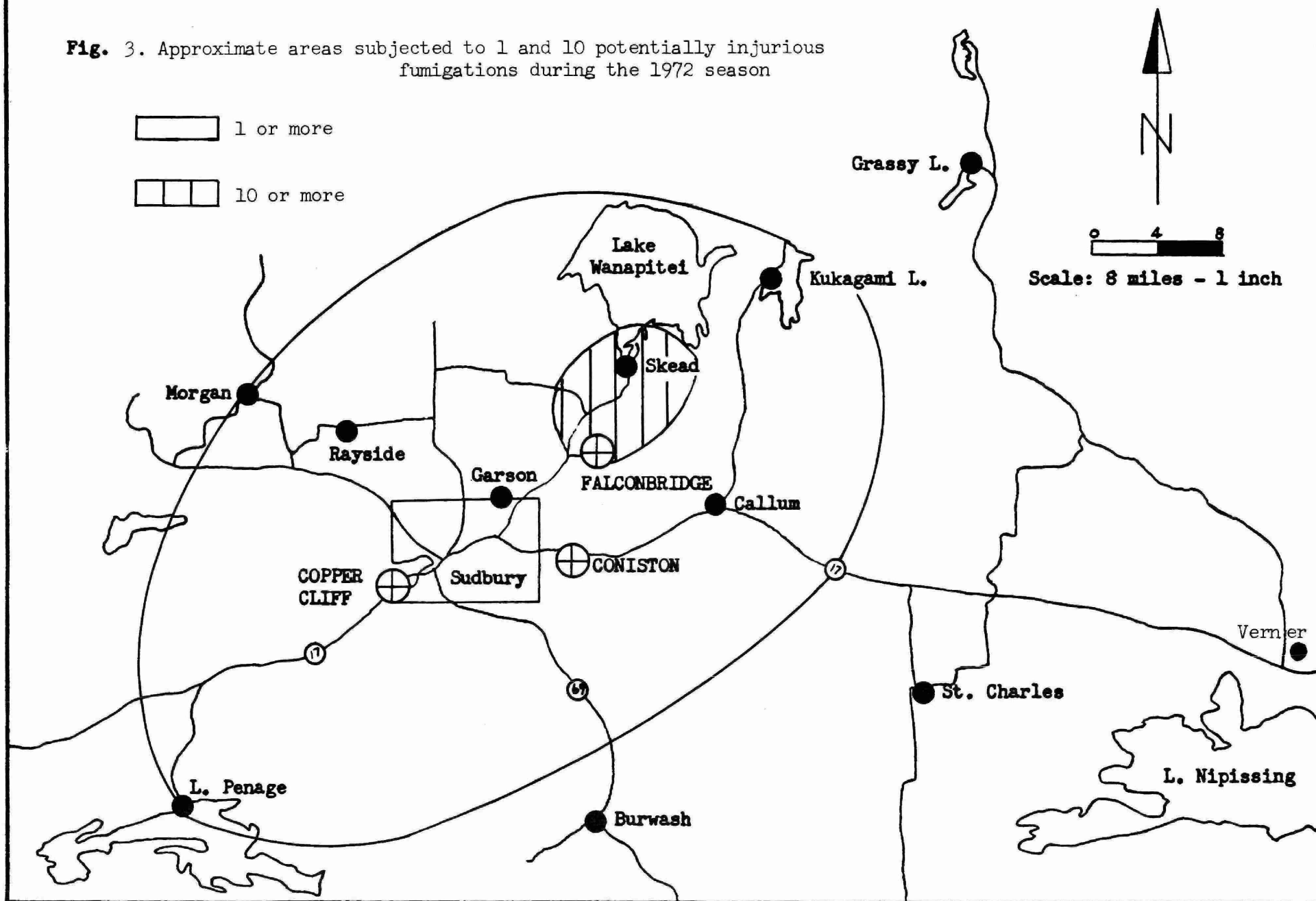


Fig. 4.

- Sudbury area Sampling Stations - Vegetation and Soil
(check stations at Blind River and Mattawa)

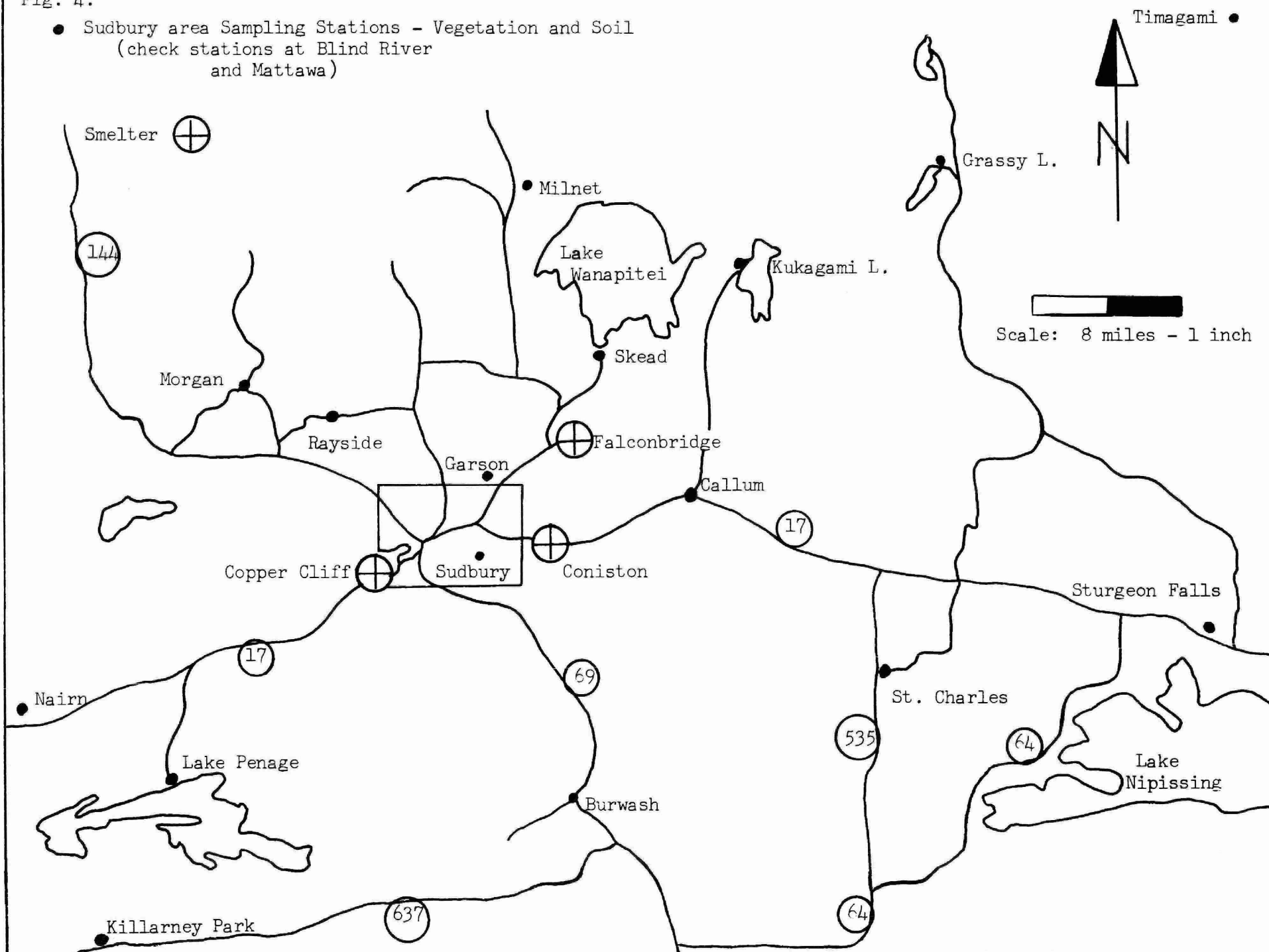


Fig. 5.

Relationship between the air candle sulphation rate
and Total Sulphur (%) in Vegetation Samples
Sudbury area 1970

$$r = 0.73$$
$$Y = 0.11x + 0.180$$

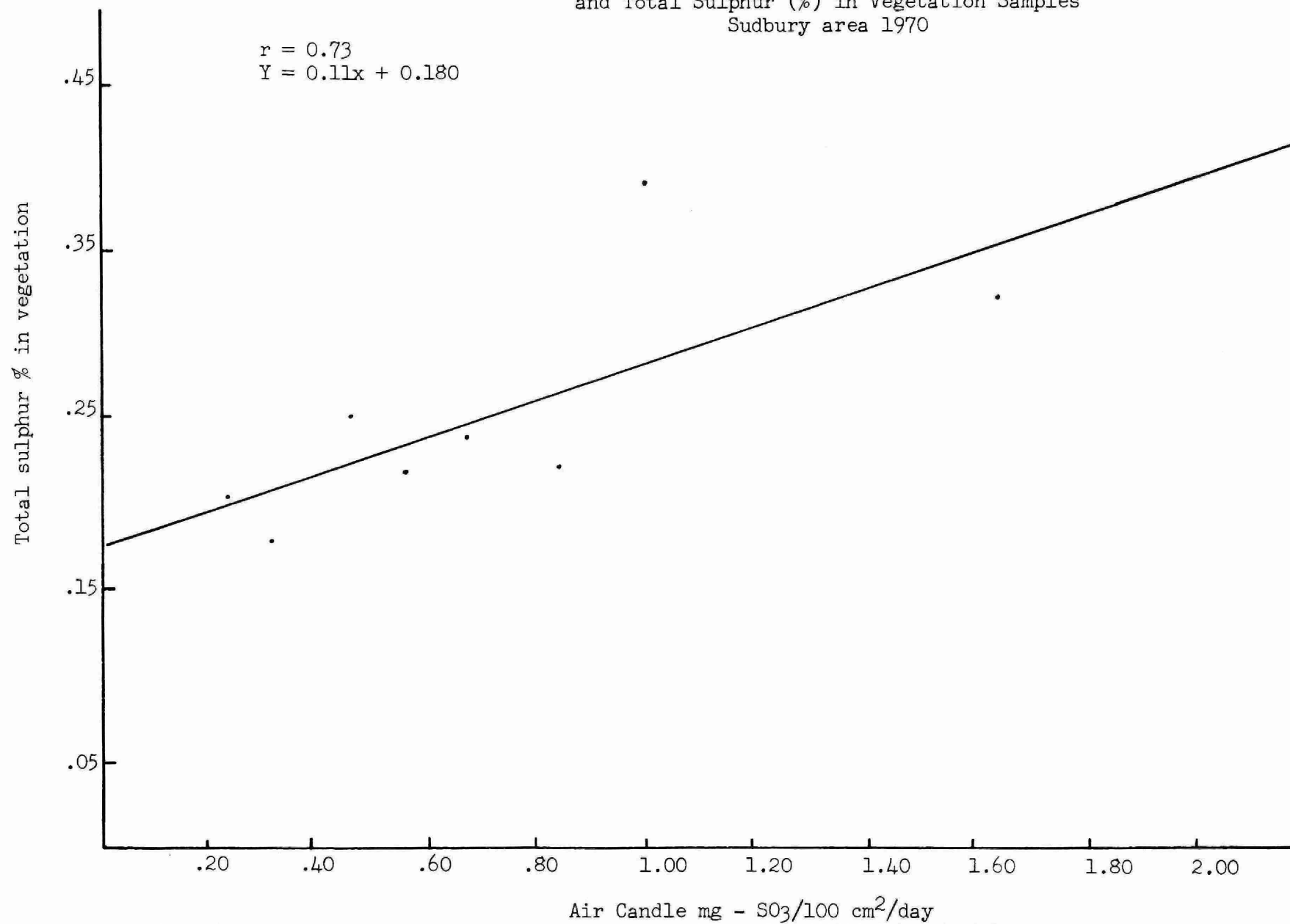


Fig. 6.

Relationship between the air candle sulphation rate
and Total Sulphur (%) in Vegetation Samples
Sudbury area 1971

$$r = 0.96$$
$$Y = 0.18x + 0.18$$

Total Sulphur % in Vegetation

.40

.20

.50

1.0

1.5

Air Candle $\text{mg} - \text{SO}_3 / 100 \text{ cm}^2 / \text{day}$

Fig. 7.

5, 10, and 20 mile Radii from each of the Sudbury Area Smelters



Smelter



SO₂ Monitor

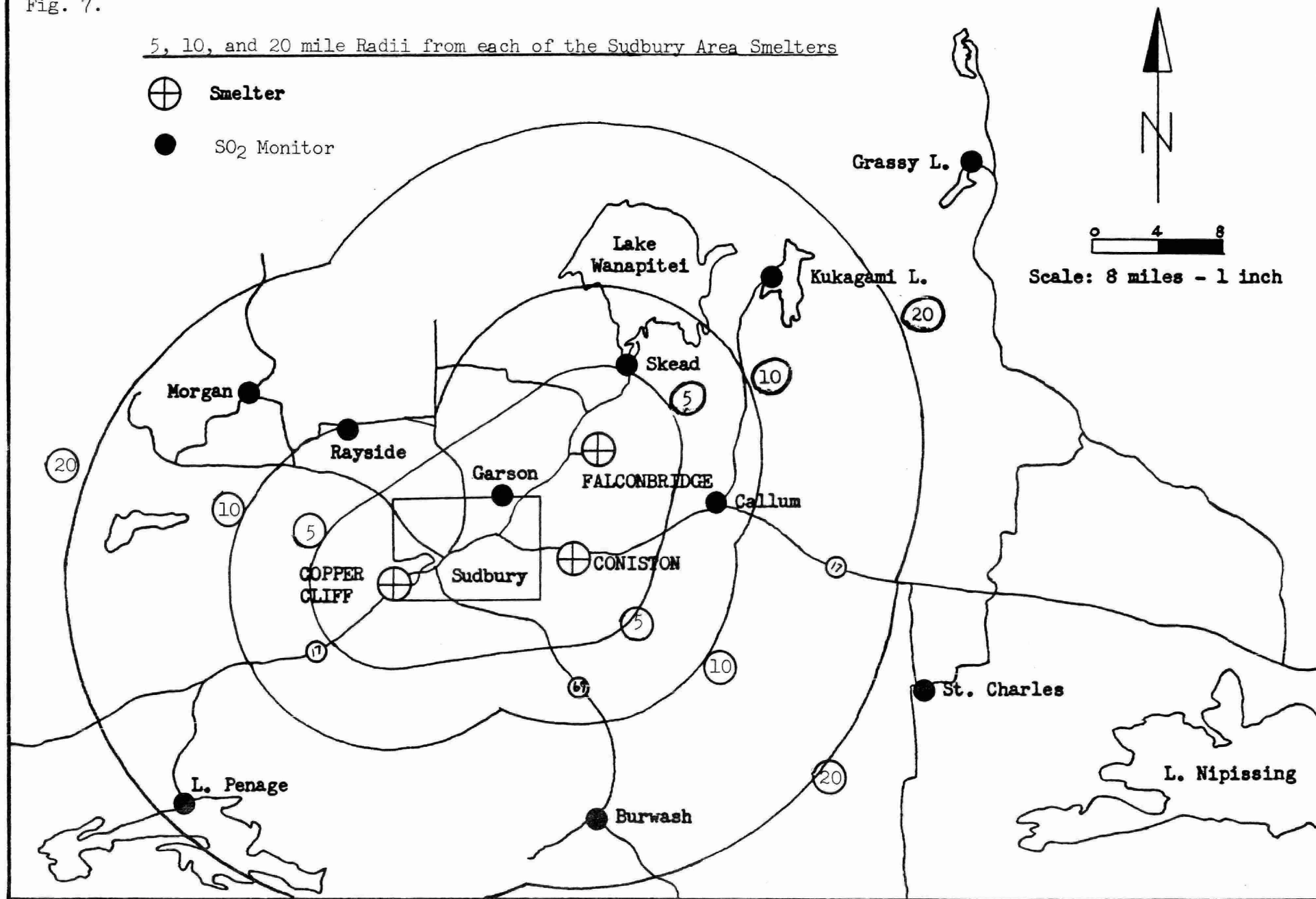


Fig. 8. ● Sudbury area snow sampling stations
(check stations at Blind River
and Mattawa)

Area of elevated ToS _____

Area of elevated Cu, Fe, Ni - - - - -

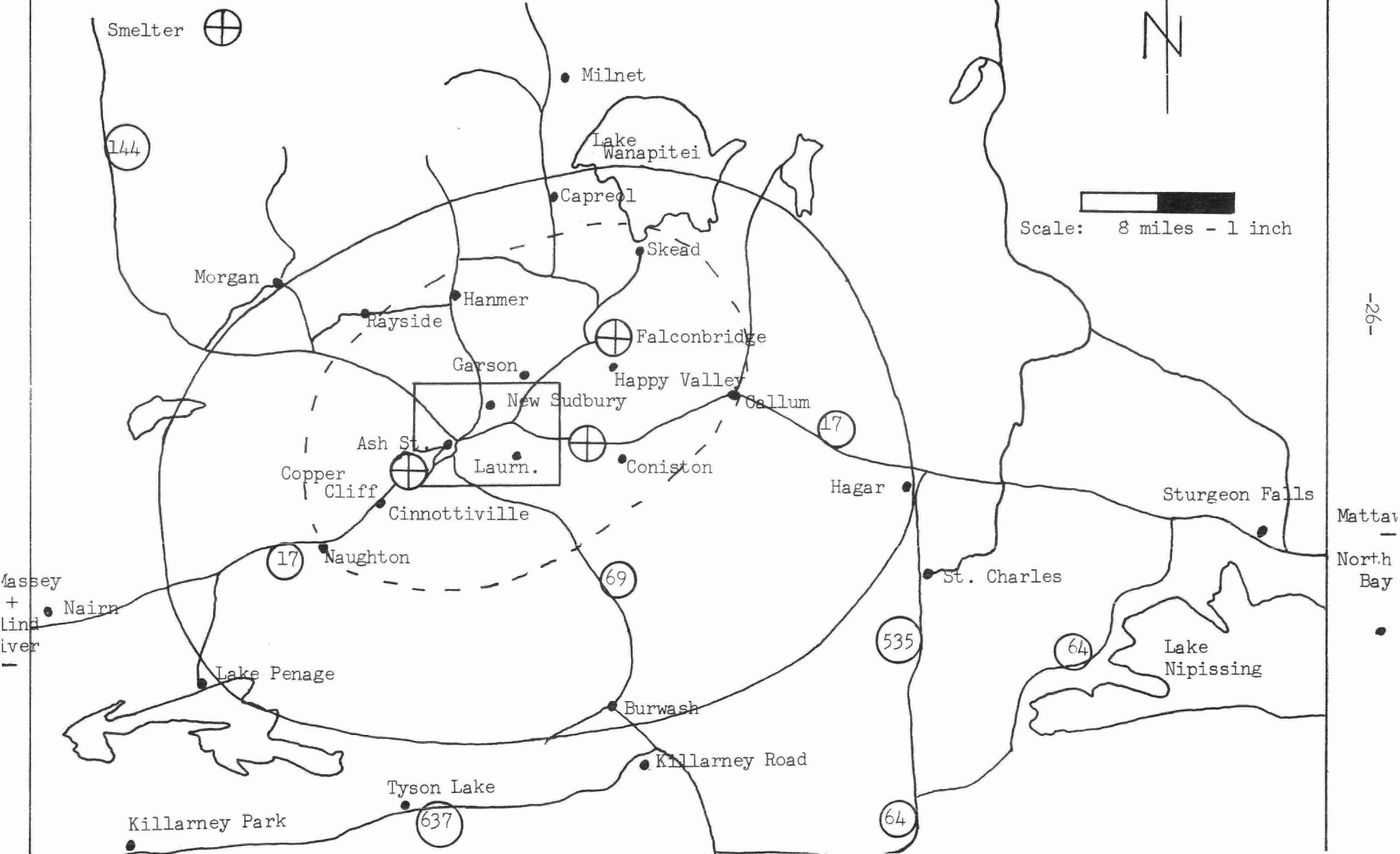


Table 1: 1972 summary of sulphur dioxide data collected at air sampling stations

Station	SO ₂ hrs. %		Half-hour concentrations above						Max. ppm $\frac{1}{2}$ -hr.	Average concentration (ppm) for			
			.25 ppm		.50 ppm		1.00 ppm			SO ₂ periods only		Total period	
			hrs.	%	hrs.	%	hrs.	%		Mean*	1972	Mean*	1972
-May-													
Garson	109.5	19.9	14.0	2.6	4.0	0.7	0.5	0.1	1.79	.141	.127	.030	.025
Skead	88.5	17.9	17.5	3.5	6.0	1.2	2.5	1.2	1.34	.198	.176	.039	.032
Kukagami	-	-	-	-	-	-	-	-	-	.092	-	.018	-
Grassy	-	-	-	-	-	-	-	-	-	.069	-	.006	-
Penage	259.5	59.9	11.5	2.7	2.5	0.6	0.0	0.0	0.84	.127	.051	.011	.030
Morgan	47.5	9.7	2.0	0.4	0.0	0.0	0.0	0.0	0.42	.085	.092	.008	.009
Burwash	27.5	6.6	1.0	0.2	0.0	0.0	0.0	0.0	0.28	.084	.062	.011	.004
Rayside	5.0	3.5	3.0	2.1	3.0	2.1	0.0	0.0	0.84	.148	.448	.018	.013
St. Charles	-	-	-	-	-	-	-	-	-	.046	-	.002	-
Callum	64.5	16.3	3.0	0.8	2.0	0.5	0.5	0.1	1.37	.082	.049	.012	.008
Verner**	322.5	68.5	2.0	0.4	0.5	0.1	0.0	0.0	0.58	-	.016	-	.011
-June-													
Garson	96.5	13.5	23.5	3.3	7.0	0.1	0.0	0.0	0.97	.172	.026	.042	.022
Skead	106.5	15.9	22.5	3.4	5.5	0.8	0.0	0.0	0.93	.198	.165	.490	.026
Kukagami	451.5	69.0	9.5	1.5	2.0	0.3	0.0	0.0	0.71	.092	.031	.180	.021
Grassy	639.5	89.6	0.0	0.0	0.0	0.0	0.0	0.0	0.24	.077	.018	.009	.016
Penage	334.0	48.1	4.0	0.6	0.0	0.0	0.0	0.0	0.35	.144	.019	.013	.009
Morgan	56.0	7.9	6.0	0.9	1.5	0.2	0.0	0.0	0.70	.094	.088	.006	.007
Burwash	2.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.06	.086	.062	.011	.002
Rayside	44.0	6.2	8.0	1.1	2.5	0.4	0.0	0.0	0.63	.134	.127	.010	.008
St. Charles	78.5	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.18	.054	.015	.003	.003
Callum	274.5	40.9	5.5	0.8	2.5	0.4	0.0	0.0	0.68	.054	.032	.003	.013
Verner**	88.5	73.8	0.0	0.0	0.0	0.0	0.0	0.0	0.09	-	.015	-	.004

* Mean is average for period from when station was established through 1971, excluding 1958, 1966, and 1969

** Data available for one season only

Table 1 (cont'd):

1972 summary of sulphur dioxide data collected at air sampling stations

Station	SO ₂ hrs. %	Half-hour concentrations above						Max. ppm $\frac{1}{2}$ -hr.	Average concentration (ppm) for			
		.25 ppm		.50 ppm		1.00 ppm			SO ₂ periods only		Total period	
			hrs.	%	hrs.	%	hrs.	%	Mean*	1972	Mean*	1972
-July-												
Garson	109.5	14.9	19.5	2.7	4.0	0.5	1.5	0.2	1.99	.170	.150	.035 .022
Skead	105.5	20.4	14.5	2.8	5.5	1.1	0.5	0.1	1.33	.175	.126	.039 .026
Kukagami	537.0	74.7	2.5	0.4	0.5	0.1	0.0	0.0	0.60	.086	.024	.016 .018
Grassy	208.5	28.3	1.0	0.1	0.0	0.0	0.0	0.0	0.32	.068	.023	.008 .065
Penage	296.0	62.5	1.5	0.3	0.5	0.1	0.0	0.0	0.51	.100	.015	.004 .009
Morgan	17.0	2.3	3.0	0.5	1.0	0.1	0.0	0.0	0.51	.081	.121	.005 .003
Burwash	13.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	.094	.023	.013 .004
Rayside	51.0	7.1	6.0	1.1	2.5	0.4	0.0	0.0	0.73	.165	.137	.010 .011
St. Charles	114.5	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.07	.054	.018	.005 .003
Callum	186.5	25.2	0.5	0.1	0.0	0.0	0.0	0.0	0.42	.090	.030	.015 .007
Verner**	88.0	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.13	-	.026	- .004
-August-												
Garson	16.0	2.7	2.5	0.3	0.0	0.0	0.0	0.0	0.47	.158	.117	.031 .003
Skead	260.5	35.5	8.0	1.1	1.5	0.2	0.0	0.0	0.06	.160	.039	.034 .014
Kukagami	507.5	96.8	0.0	0.0	0.0	0.0	0.0	0.0	0.20	.092	.012	.014 .011
Grassy	15.0	32.6	0.0	0.0	0.0	0.0	0.0	0.0	0.03	.064	.008	.006 .003
Penage	210.5	32.4	0.0	0.0	0.0	0.0	0.0	0.0	0.09	.109	.011	.008 .037
Morgan	2.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.08	.074	.044	.005 .001
Burwash	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	.087	.000	.010 .000
Rayside	12.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.25	.124	.065	.010 .001
St. Charles	201.5	36.1	0.0	0.0	0.0	0.0	0.0	0.0	0.10	.053	.022	.004 .008
Callum	200.0	32.8	0.5	0.1	0.0	0.0	0.0	0.0	0.36	.098	.021	.017 .007
Verner**	227.0	32.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	-	.016	- .005

* Mean is average for period from when station was established through 1971, excluding 1958, 1966, and 1969

** Data available for one season only

Table 1 (cont'd):

1972 summary of sulphur dioxide data collected at air sampling stations

Station	SO ₂		Half-hour concentrations above						Max. ppm $\frac{1}{2}$ -hr.	Average concentration (ppm) for			
			.25 ppm		.50 ppm		1.00 ppm			SO ₂ periods only		Total period	
	hrs.	%	hrs.	%	hrs.	%	hrs.	%		Mean*	1972	Mean*	1972
-September-													
Garson	65.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.24	.152	.051	.025	.005
Skead	221.5	30.9	12.0	1.7	2.0	0.3	0.0	0.0	0.77	.139	.071	.049	.022
Kukagami	104.0	44.6	0.0	0.0	0.0	0.0	0.0	0.0	0.61	.093	.014	.013	.006
Grassy	595.0	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.08	.070	.016	.006	.002
Penage	126.0	18.6	1.0	0.2	0.0	0.0	0.0	0.0	0.32	.109	.021	.006	.004
Morgan	10.5	1.5	1.0	0.1	0.0	0.0	0.0	0.0	0.34	.080	.090	.006	.001
Burwash	17.0	2.9	2.0	0.3	0.0	0.0	0.0	0.0	0.40	.100	.249	.012	.007
Rayside	50.0	7.7	1.0	0.2	0.0	0.0	0.0	0.0	0.27	.147	.066	.016	.005
St. Charles	319.0	50.8	0.0	0.0	0.0	0.0	0.0	0.0	0.07	.050	.017	.004	.017
Callum	141.0	20.6	2.5	0.4	0.0	0.0	0.0	0.0	0.40	.098	.034	.014	.007
Verner**	219.5	30.6	1.0	0.1	0.0	0.0	0.0	0.0	0.27	-	.011	-	.005
-October-													
Garson	23.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	.142	.027	.024	.001
Skead	228.5	38.4	27.5	4.6	5.0	0.8	0.5	0.8	1.17	.250	.105	.050	.040
Kukagami	101.5	42.9	0.5	0.2	0.0	0.0	0.0	0.0	0.48	.101	.027	.014	.012
Grassy	-	-	-	-	-	-	-	-	-	.070	-	.006	-
Penage	98.0	25.1	0.5	0.1	0.0	0.0	0.0	0.0	0.26	.120	.019	.007	.005
Morgan	8.5	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.21	.078	.081	.008	.000
Burwash	34.5	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.12	.099	.036	.014	.002
Rayside	41.0	5.6	2.0	0.3	0.0	0.0	0.0	0.0	0.34	.102	.073	.012	.004
St. Charles	-	-	-	-	-	-	-	-	-	.046	-	.004	-
Callum	64.0	9.8	1.0	0.2	0.0	0.0	0.0	0.0	0.34	.096	.049	.012	.004
Verner**	363.5	49.6	0.0	0.0	0.0	0.0	0.0	0.0	0.18	-	.001	-	.007

* Mean is average for period from when station was established through 1971, excluding 1958, 1966, and 1969

** Data available for one season only

Table 2: Number of half-hour concentrations of SO₂ (ppm) - 1972

<u>Garson</u>	<u>Above 1.00</u>	<u>Above .50</u>	<u>Above .25</u>
May	1	7	28
June	0	14	48
July	3	5	39
August	0	0	5
September	0	0	0
October	0	0	0
Season	4	26	120
<u>Skead</u>			
May	5	7	36
June	0	11	47
July	1	10	30
August	0	2	17
September	0	4	27
October	1	9	59
Season	7	43	216
<u>Kukagami Lake</u>			
May			
June	0	4	20
July	0	1	5
August	0	0	0
September	0	1	2
October	0	0	2
Season	0	6	29
<u>Grassy Lake</u>			
May	0	0	0
June	0	0	0
July	0	0	2
August	0	0	0
September	0	0	0
October	0	0	0
Season	0	0	2
<u>Penage</u>			
May	0	5	26
June	0	0	9
July	0	1	3
August	0	0	0
September	0	0	2
October	0	0	1
Season	0	6	41
<u>Morgan</u>			
May	0	0	4
June	0	3	12
July	0	1	7
August	0	0	0
September	0	0	2
October	0	0	0
Season	0	4	25

Table 2 (cont'd): Number of half-hour concentrations of SO₂ (ppm) - 1972

<u>Burwash</u>	<u>Above 1.00</u>	<u>Above .50</u>	<u>Above .25</u>
May	0	0	2
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	8
October	0	0	0
Season	0	0	10
<u>Rayside</u>			
May	0	6	6
June	0	5	16
July	0	5	12
August	0	0	0
September	0	0	2
October	0	0	4
Season	0	16	40
<u>St. Charles</u>			
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
Season	0	0	0
<u>Callum</u>			
May	1	3	6
June	0	5	11
July	0	0	1
August	0	0	1
September	0	0	5
October	0	0	2
Season	1	8	26
<u>Verner</u>			
May	0	1	4
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	2
October	0	0	0
Season	0	1	6

Table 3: Yearly summary of SO₂ data for the Sudbury area

Station	Low	Year	High	Year	1972
* Percentage frequency of SO ₂					
Garson	10.72	1972	25.02	1962	10.72
Skead	13.40	1954	36.50	1971	27.14
Kukagami	7.78	1954	71.87	1972	71.87
Grassy	3.39	1954	43.81	1972	43.81
Penage	4.59	1953	39.89	1972	39.89
Morgan	3.43	1972	14.20	1971	3.43
Burwash	2.62	1972	21.39	1962	2.62
Rayside	4.37	1957	13.85	1968	5.57
St. Charles	3.65	1957	30.73	1972	30.73
Callum	11.85	1970	24.79	1972	24.79
**Verner	-	-	-	-	37.18

* Percentage frequency of SO ₂ above 0.25 ppm					
Garson	1.13	1953	5.14	1960	1.52
Skead	2.75	1972	8.12	1961	2.75
Kukagami	0.29	1954	1.80	1967	0.53
Grassy	0.00	1953	0.78	1961	0.04
Penage	0.33	1962	1.27	1954	0.56
Morgan	0.16	1968	0.93	1962	0.30
Burwash	0.09	1972	1.84	1960	0.09
Rayside	0.52	1972	2.29	1970	0.52
St. Charles	0.00	1971	0.34	1961	0.00
Callum	0.53	1962	1.65	1963	0.35
**Verner	-	-	-	-	0.09

Maximum half-hour concentrations (ppm)					
Garson	1.16	1953	3.06	1962	1.99
Skead	1.31	1959	3.64	1956	1.34
Kukagami	0.49	1956	1.24	1961	0.71
Grassy	0.24	1953	0.77	1966	0.32
Penage	0.44	1969	1.65	1965	0.84
Morgan	0.52	1964	1.24	1967	0.70
Burwash	0.40	1972	1.39	1954	0.40
Rayside	0.84	1972	1.71	1970	0.84
St. Charles	0.18	1972	0.95	1959	0.18
Callum	0.62	1969	1.63	1965	1.37
**Verner	-	-	-	-	0.58

*Does not include 1958, 1966, and 1969 (strike years)
 **Data available for 1971 season only

Table 4: Number of potentially injurious fumigations recorded during 1972 and the
maximum intensity recorded at each of the 11 Sudbury area air sampling stations

STATION	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	TOTAL
Garson	1 (197)	3 (173)	2 (184)	0 (52)	0 (39)	0 (8)	6
Skead	4 (123)	2 (155)	3 (121)	1 (125)	1 (109)	2 (180)	13
Kukagami Lake		1 (137)	0 (54)	0 (19)	0 (50)	0 (18)	1
Grassy Lake	0 (5)	0 (35)	0 (38)	0 (6)	0 (10)	0 (9)	0
Penage	1 (116)	0 (81)	0 (73)	0 (10)	0 (41)	0 (41)	1
Morgan	0 (79)	1 (109)	0 (75)	0 (10)	0 (53)	0 (39)	1
Burwash	0 (40)	0 (9)	0 (7)	0 (0)	0 (40)	0 (23)	0
Rayside	1 (158)	1 (125)	1 (105)	0 (26)	0 (46)	0 (61)	3
St. Charles	0 (3)	0 (16)	0 (9)	0 (12)	0 (13)	0 (1)	0
Callum	1 (148)	1 (139)	0 (35)	0 (68)	0 (30)	0 (38)	2
Verner	0 (64)	0 (6)	0 (19)	0 (14)	0 (57)	0 (33)	0
TOTAL	8	9	6	1	1	2	27

Table 5: Concentrations of the various Elements in White Birch samples collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of four (1970) or three (1971) monthly collections).

White Birch		Chemicals													
Plots	*Location	ToS 1970	% 1971	As 1970	ppm 1971	Co 1970	ppm 1971	Cu 1970	ppm 1971	Fe 1970	ppm 1971	Ni 1970	ppm 1971	Zn 1970	ppm 1971
Blind River	100 m. W	.12	.14	0.5	0.6	2.0	10	8	7	54	97	3	8	296	607
Mattawa	110 m. E	.17	.13	0.6	1.1	2.0	5	10	6	54	74	3	5	270	157
Sudbury	Laurn. U.	<u>.29</u>	<u>.35</u>	0.6	<u>2.8</u>	3.0	6	26	23	<u>162</u>	<u>311</u>	<u>58</u>	<u>81</u>	90	84
Garson	3 m. NE	<u>.41</u>	<u>.48</u>	2.0	<u>5.4</u>	2.0	3	<u>61</u>	<u>48</u>	<u>235</u>	<u>360</u>	<u>84</u>	<u>81</u>	114	66
Skead	16 m. NE	<u>.37</u>	<u>.36</u>	<u>4.4</u>	<u>3.6</u>	2.4	5	<u>59</u>	25	<u>423</u>	<u>342</u>	<u>97</u>	<u>72</u>	188	129
Kukagami L.	26 m. NE	<u>.27</u>	<u>.29</u>	2.2	1.9	2.2	5	<u>39</u>	14	<u>321</u>	<u>133</u>	<u>46</u>	<u>25</u>	213	160
Grassy L.	40 m. NE	<u>.18</u>	<u>.24</u>	0.5	1.5	2.2	5	11	10	<u>103</u>	95	13	11	237	143
Timagami	50 m. NE	<u>.22</u>	<u>.21</u>	0.6	1.3	2.2	6	20	11	<u>137</u>	<u>345</u>	14	10	151	250
Rayside	10 m. NW	<u>.24</u>	<u>.22</u>	0.7	1.6	2.2	4	24	21	<u>130</u>	<u>447</u>	<u>45</u>	<u>40</u>	87	188
Morgan	15 m. NW	<u>.17</u>	<u>.31</u>	0.5	1.4	2.2	5	19	16	<u>140</u>	<u>267</u>	18	23	205	280
Milnet	23 m. N	<u>.25</u>	.15	1.4	1.7	2.2	4	26	9	<u>141</u>	<u>147</u>	<u>42</u>	16	158	150
Callum	18 m. E	<u>.24</u>	<u>.33</u>	1.1	1.4	2.2	7	23	14	<u>125</u>	<u>187</u>	<u>44</u>	<u>45</u>	125	210
St. Charles	30 m. SE	.15	.20	0.7	1.0	2.2	8	16	8	<u>110</u>	<u>176</u>	16	13	239	207
Sturgeon Falls	48 m. E	.17	.19	0.7	1.4	2.2	6	12	8	<u>44</u>	122	7	8	291	235
Burwash	17 m. S	<u>.26</u>	<u>.23</u>	0.7	1.4	2.2	4	23	12	<u>186</u>	<u>156</u>	<u>31</u>	<u>25</u>	76	287
Nairn Centre	30 m. SW	.17	.18	0.6	1.7	2.2	8	10	11	75	92	8	13	223	349
Penage	23 m. SW	.17	.21	0.5	1.2	2.2	4	22	9	74	71	13	10	176	237

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls
- Blind River and Mattawa are control plots

Table 5(cont'd): Concentrations of the Various Chemical Elements in the Trembling Aspen samples collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of four (1970) or three (1971) monthly collections).

Trembling Aspen

Chemicals

Plot	*Location	ToS 1970	% 1971	As 1970	ppm 1971	Co 1970	ppm 1971	Cu 1970	ppm 1971	Fe 1970	ppm 1971	Ni 1970	ppm 1971	Zn 1970	ppm 1971
Blind River	100 m. W	.16	.22	0.5	0.8	2.0	10	6	10	45	62	3	6	283	265
Mattawa	110 m. E	.19	.22	0.6	0.8	2.0	5	11	8	62	81	3	5	262	212
Sudbury	Laurn. U	.33	.42	0.5	<u>2.5</u>	0.4	12	17	14	<u>125</u>	<u>362</u>	<u>54</u>	<u>136</u>	84	124
Garson	3 m. NE	.44	.49	0.6	<u>4.9</u>	3.7	6	<u>27</u>	<u>29</u>	<u>144</u>	<u>317</u>	<u>99</u>	<u>59</u>	75	125
Skead	16 m. NE	.37	.50	<u>3.8</u>	<u>3.4</u>	3.5	6	<u>38</u>	15	<u>437</u>	<u>242</u>	<u>83</u>	<u>76</u>	176	141
Kukagami L.	26 m. NE	.40	.36	0.6	1.5	3.0	11	<u>22</u>	12	<u>184</u>	<u>173</u>	<u>45</u>	<u>58</u>	225	187
Grassy L.	40 m. NE	.22	.40	0.5	2.1	2.0	12	10	10	69	101	18	16	163	152
Timagami	50 m. NE	.33	.37	0.5	1.5	2.0	6	<u>21</u>	11	<u>159</u>	<u>317</u>	15	13	109	202
Rayside	10 m. NW	.20	.26	0.9	1.2	4.6	6	<u>28</u>	10	<u>167</u>	<u>286</u>	<u>95</u>	<u>73</u>	127	111
Morgan	15 m. NW	.20	.25	0.5	1.0	2.4	6	<u>17</u>	9	<u>188</u>	<u>132</u>	<u>28</u>	<u>31</u>	156	215
Milnet	23 m. N	.26	.27	0.9	0.9	2.8	6	<u>23</u>	9	<u>159</u>	94	<u>78</u>	20	238	141
Callum	18 m. E	.27	.43	1.0	2.0	3.7	13	<u>14</u>	12	98	<u>150</u>	<u>96</u>	<u>105</u>	131	280
St. Charles	30 m. SE	.20	.29	0.8	2.5	3.3	11	15	9	<u>124</u>	<u>175</u>	12	17	171	217
Sturgeon Falls	48 m. E	.18	.33	0.5	1.1	2.0	10	10	11	45	<u>130</u>	9	9	570	262
Burwash	17 m. S	.32	.31	0.7	1.4	2.0	7	<u>21</u>	11	<u>173</u>	<u>178</u>	<u>36</u>	<u>62</u>	125	232
Nairn Centre	30 m. SW	.21	.25	0.6	0.6	3.0	8	<u>11</u>	11	81	<u>102</u>	15	17	265	233
Penage	23 m. SW	.23	.32	0.5	1.4	3.1	9	19	10	74	98	<u>28</u>	13	191	130

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls
- Blind River and Mattawa are control plots

Table 5(cont'd): Concentrations of the Various Chemical Elements in sample of current-year Jack Pine Needles collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of four (1970) or two (1971) monthly collections).

Jack Pine Needles (current-year)		<u>Chemicals</u>													
Plots	*Location	ToS	%	As	ppm	Co	ppm	Cu	ppm	Fe	ppm	Ni	ppm	Zn	ppm
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Blind River	100 m. W	.10	.11	0.5	0.8	2.0	5	2	5	24	47	2	14	66	70
Mattawa	110 m. E	.12	.11	0.5	0.9	2.0	2	5	5	36	54	3	6	74	66
Sudbury	Laurn. U.	.14	.14	0.5	2.0	2.0	5	9	9	47	<u>111</u>	26	28	53	24
Garson	3 m. NE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Skead	16 m. NE	.22	.23	1.7	<u>6.4</u>	2.0	4	<u>28</u>	<u>18</u>	<u>306</u>	<u>403</u>	<u>60</u>	<u>45</u>	29	27
Kukagami L.	26 m. NE	.19	.18	0.6	1.2	2.0	6	15	8	<u>118</u>	<u>91</u>	<u>39</u>	23	29	52
Grassy L.	40 m. NE	.11	.14	0.5	0.8	2.0	3	6	7	60	60	16	22	44	43
Timagami	50 m. NE	.14	.17	0.6	1.2	2.0	3	12	5	<u>97</u>	<u>115</u>	18	13	74	62
Rayside	10 m. NW	.14	.14	0.5	1.9	2.0	5	13	6	<u>113</u>	<u>351</u>	<u>40</u>	<u>30</u>	23	33
Morgan	15 m. NW	.15	.23	0.6	1.9	2.0	11	8	4	91	<u>180</u>	15	26	40	88
Milnet	23 m. N	.14	.12	0.5	1.4	2.0	5	18	6	84	<u>76</u>	<u>25</u>	19	55	40
Callum	18 m. E	.16	.14	0.7	1.5	2.0	5	9	8	52	75	<u>32</u>	<u>34</u>	20	30
St. Charles	30 m. SE	.10	.13	0.5	0.7	2.0	3	5	7	64	<u>173</u>	9	12	47	44
Sturgeon Falls	48 m. E	-	.13	-	0.8	2.0	2	-	7	-	90	-	10	-	68
Burwash	17 m. S	.12	.14	0.5	0.9	2.0	3	6	6	70	<u>128</u>	22	17	30	38
Nairn Centre	30 m. SW	.12	.11	0.5	0.7	2.0	4	3	6	40	<u>61</u>	14	15	46	64
Penage	23 m. SW	.13	.16	0.5	1.0	2.0	4	8	10	<u>294</u>	<u>105</u>	39	11	30	55

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls
- Blind River and Mattawa are control plots

Table 5(cont'd):Concentrations of the Various Chemical Elements in samples of one-year-old Jack Pine Needles collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of four (1970) or three (1971) monthly collections).

Jack Pine Needles
(one-year-old)

Chemicals

Plots	*Location	ToS %		As ppm		Co ppm		Cu ppm		Fe ppm		Ni ppm		Zn ppm	
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Blind River	100 m. W	.07	.08	0.5	1.2	2.0	3	2	5	35	43	1	6	42	47
Mattawa	110 m. E	.09	.10	0.5	1.3	2.0	3	6	4	62	84	6	3	83	92
Sudbury	Laurn. U.	.14	<u>.21</u>	0.5	<u>3.7</u>	2.0	5	21	13	<u>191</u>	<u>305</u>	<u>36</u>	<u>35</u>	17	23
Garson	3 m. NE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Skead	16 m. NE	.26	.22	<u>5.8</u>	<u>11.0</u>	2.0	2	<u>55</u>	26	<u>503</u>	<u>784</u>	<u>55</u>	<u>44</u>	15	28
Kukagami L.	26 m. NE	<u>.18</u>	<u>.17</u>	<u>2.0</u>	<u>1.6</u>	2.0	5	<u>35</u>	8	<u>239</u>	<u>197</u>	<u>35</u>	<u>17</u>	40	43
Grassy L.	40 m. NE	.09	.13	0.5	1.8	2.0	4	9	6	93	91	9	11	33	41
Timagami	50 m. NE	.10	.15	0.5	1.4	2.0	2	10	4	<u>132</u>	<u>183</u>	10	8	52	68
Rayside	10 m. NW	.12	.11	0.8	<u>2.5</u>	2.0	4	<u>38</u>	10	<u>141</u>	<u>206</u>	<u>38</u>	<u>29</u>	24	31
Morgan	15 m. NW	.12	.15	0.5	1.5	2.0	3	<u>17</u>	9	<u>119</u>	<u>262</u>	13	<u>16</u>	33	40
Milnet	23 m. N	.14	.14	0.9	1.6	2.0	3	<u>34</u>	11	105	150	<u>34</u>	17	48	40
Callum	18 m. E	.12	.15	0.8	1.8	2.0	4	15	10	125	<u>162</u>	<u>37</u>	<u>31</u>	28	25
St. Charles	30 m. SE	.12	.14	0.5	1.5	2.0	4	6	7	99	<u>259</u>	5	10	45	38
Sturgeon Falls	48 m. E	-	.14	-	2.0	-	5	-	7	-	119	-	12	-	5
Burwash	17 m. S	.16	.17	0.8	2.0	2.0	3	11	7	118	<u>169</u>	17	18	31	44
Nairn Centre	30 m. SW	.12	.14	0.5	1.1	2.0	4	10	6	69	<u>112</u>	6	12	55	78
Penage	23 m. SW	.13	.13	0.6	2.0	2.0	8	17	7	56	118	8	8	46	13

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls

- Blind River and Mattawa are control plots

Table 5(cont'd) Concentrations of the Various Chemical Elements in the Bracken Fern samples collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons. (Average of four (1970) and two (1971) monthly collections).

Bracken Fern		Chemicals													
Plots	**Location	ToS	%	As	ppm	Co	ppm	Cu	ppm	Fe	ppm	Ni	ppm	Zr	ppm
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Blind River	100 m. W	.10	.13	0.5	1.5	2	7	3	6	61	83	1	6	29	*32
Mattawa	110 m. E	.14	.14	0.5	0.9	2	4	9	6	77	91	2	4	51	47
Sudbury	Laurn. U.	.21	.22	0.5	2.7	2	8	21	20	115	181	66	30	54	25
Garson	3 m. NE	.22	.31	0.9	3.3	2	5	24	20	160	212	67	24	29	34
Skead	16 m. NE	.26	.28	2.3	3.4	2	6	17	14	211	200	36	27	34	40
Kukagami L.	26 m. NE	.19	.30	0.7	1.4	2	10	10	10	108	144	24	42	33	*20
Grassy L.	40 m. NE	.14	.19	0.8	1.9	2	4	6	9	99	168	3	6	29	26
Timagami	50 m. NE	.15	.16	0.5	1.2	2	6	13	9	162	267	6	8	34	41
Rayside	10 m. NW	.21	.21	0.5	1.4	2	5	16	11	136	169	51	29	26	33
Morgan	15 m. NW	.20	.18	0.5	0.7	2	4	8	7	103	128	7	6	19	33
Milnet	23 m. N	.16	.18	0.6	1.3	2	4	13	7	112	116	20	10	30	23
Callum	18 m. E	.18	.30	1.0	2.6	2	8	20	9	182	116	42	18	21	25
St. Charles	30 m. SE	.13	.14	0.5	1.5	2	7	8	8	152	123	6	8	29	29
Sturgeon Falls	48 m. E	.12	.19	0.6	1.8	2	7	4	8	65	141	2	9	35	69
Burwash	17 m. S	.19	.28	0.8	1.3	2	8	20	8	164	124	23	5	28	26
Nirn Centre	30 m. SW	.13	.19	0.6	0.7	2	7	2	7	102	91	9	10	33	51
Penage	23 m. SW	.14	.16	1.3	2.6	2	4	9	6	106	128	9	5	38	*21

** Distance and Direction from Sudbury

* Based on one monthly collection

- underlined values are markedly higher than the controls

- Blind River and Mattawa are control plots

Table 5(cont'd) Concentrations of the Various Chemical Elements in the Forage (not washed) samples collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of four (1970) or three (1971) monthly collections).

Forage (not washed)		<u>Chemicals</u>													
Plot	*Location	ToS	%	As	ppm	Co	ppm	Cu	ppm	Fe	ppm	Ni	ppm	Zn	ppm
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Blind River	100 m. W	.14	.19	0.5	0.9	2	3	9	5	40	70	2	2	29	28
Mattawa	110 m. E	.20	.15	0.5	1.1	2	5	9	6	100	122	3	8	36	43
Sudbury	Laurn. U	.22	.22	0.5	2.0	2	9	18	7	<u>121</u>	<u>291</u>	<u>24</u>	<u>34</u>	20	37
Garson	3 m. NE	<u>.40</u>	<u>.28</u>	2.1	<u>3.5</u>	2	4	<u>35</u>	12	<u>122</u>	<u>267</u>	<u>15</u>	<u>36</u>	20	21
Skead	16 m. NE	<u>.41</u>	<u>.40</u>	1.2	<u>3.7</u>	2	3	<u>36</u>	12	<u>234</u>	<u>281</u>	<u>33</u>	<u>29</u>	42	17
Kukagami L.	26 m. NE	<u>.31</u>	<u>.31</u>	0.5	0.8	2	5	<u>18</u>	11	<u>112</u>	<u>237</u>	<u>22</u>	<u>20</u>	40	42
Grassy L.	40 m. NE	<u>.28</u>	<u>.34</u>	0.5	1.1	2	4	12	12	73	95	6	7	35	32
Timagami	50 m. NE	<u>.19</u>	<u>.18</u>	0.5	1.5	2	5	12	7	<u>148</u>	453	3	11	27	21
Rayside	10 m. NW	<u>.27</u>	<u>.26</u>	0.5	1.9	2	2	14	7	<u>139</u>	<u>278</u>	<u>30</u>	<u>29</u>	22	25
Morgan	15 m. NW	<u>.29</u>	<u>.26</u>	0.5	1.1	2	5	13	9	<u>115</u>	<u>346</u>	<u>19</u>	5	29	36
Milnet	23 m. N	<u>.30</u>	<u>.28</u>	0.5	1.3	2	4	15	10	98	98	<u>37</u>	3	36	43
Callum	18 m. E	<u>.25</u>	<u>.25</u>	0.7	1.6	2	5	16	8	110	134	<u>30</u>	<u>29</u>	29	39
St. Charles	30 m. SE	.22	.19	0.5	1.4	2	4	10	5	97	141	7	14	27	22
Sturgeon Falls	48 m. E	.14	<u>.31</u>	0.5	1.4	2	5	11	9	82	<u>268</u>	3	9	25	42
Burwash	17 m. S	.25	<u>.24</u>	1.2	1.4	2	4	17	8	108	<u>376</u>	20	13	22	33
Nairn Centre	30 m. SW	.19	.22	0.5	1.0	2	4	8	8	59	96	5	10	19	31
Penage	23 m. SW	<u>.23</u>	<u>.21</u>	0.5	1.4	2	4	19	8	79	85	7	15	19	48

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls
- Blind River and Mattawa are control plots

Table 5(cont'd): Concentrations of the Various Chemical Elements in the Forage (washed) samples collected at the Sudbury Surveillance Plots during the 1971 growing season (Average of three monthly collections)

Forage (washed)		Chemicals						
Plot	*Location	ToS % 1971	As ppm 1971	Co ppm 1971	Cu ppm 1971	Fe ppm 1971	Ni ppm 1971	Zn ppm 1971
Blind River	100 m. W	.17	0.7	3	6	53	2	30
Mattawa	110 m. E	.15	0.9	4	6	69	6	40
Sudbury	Laurn. U.	.18	<u>1.9</u>	8	6	85	<u>27</u>	38
Garson	3 m. NE	.27	<u>2.7</u>	3	9	<u>113</u>	<u>30</u>	21
Skead	16 m. NE	<u>.41</u>	<u>2.5</u>	2	7	<u>160</u>	<u>22</u>	16
Kukagami L.	26 m. NE	<u>.30</u>	1.2	4	8	92	16	36
Grassy L.	40 m. NE	<u>.32</u>	0.7	4	11	70	4	35
Timagami	50 m. NE	.16	1.2	4	6	<u>256</u>	8	19
Rayside	10 m. NW	<u>.24</u>	1.1	2	6	<u>119</u>	<u>22</u>	14
Morgan	15 m. NW	<u>.22</u>	0.8	4	8	<u>181</u>	6	25
Milnet	23 m. N	<u>.27</u>	1.0	4	10	77	4	55
Callum	18 m. E	<u>.29</u>	1.0	5	4	69	<u>24</u>	50
St. Charles	30 m. SE	.19	1.4	4	5	96	13	20
Sturgeon Falls	48 m. E	<u>.30</u>	0.9	5	8	<u>113</u>	8	37
Burwash	17 m. S	<u>.22</u>	1.4	4	7	<u>217</u>	13	40
Nairn Centre	30 m. SW	.19	0.7	4	7	74	10	30
Penage	23 m. SW	.17	0.8	6	6	70	11	34

* Distance and Direction from Sudbury

- underlined values are markedly higher than the controls
- Blind River and Mattawa are control plots

Table 5 (cont'd) Concentrations of the Various Chemical Elements in the Soil samples collected at the Sudbury Surveillance Plots during the 1970 and 1971 growing seasons (Average of two monthly collections).

Soil		Chemicals													
Plot	**Location	ToS	%	As	ppm	Co	ppm	Cu	ppm	Fe	%	Ni	ppm	Zn	ppm
		1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
Blind River	100 m. W	.02	.03	1.7	4.4	6	5	10	18	*.15	.67	11	*2	37	42
Mattawa	110 m. E	.01	.04	2.3	3.8	2	5	7	7	.39	.65	7	*5	28	37
Sudbury	Laurin. U.	.02	.03	<u>10.2</u>	<u>18.4</u>	9	9	<u>265</u>	<u>173</u>	* <u>1.58</u>	<u>1.15</u>	<u>245</u>	<u>149</u>	30	93
Garson	3 m. NE	.03	.05	<u>9.8</u>	* <u>26.0</u>	8	5	<u>174</u>	<u>105</u>	* <u>1.02</u>	.69	<u>215</u>	<u>86</u>	23	64
Skead	16 m. NE	.04	.10	<u>13.1</u>	<u>47.0</u>	9	11	<u>125</u>	<u>170</u>	<u>1.12</u>	<u>1.20</u>	<u>150</u>	<u>135</u>	85	77
Kukagami L.	26 m. NE	.05	.06	<u>11.7</u>	6.4	*7	11	<u>102</u>	<u>35</u>	<u>1.60</u>	<u>1.28</u>	<u>85</u>	42	43	44
Grassy L.	40 m. NE	.04	.03	7.0	6.6	20	13	<u>57</u>	28	.60	<u>1.75</u>	<u>68</u>	<u>53</u>	114	72
Timagami	50 m. NE	.04	.02	4.0	7.0	10	7	<u>51</u>	22	.98	.35	40	32	53	52
Rayside	10 m. NW	.03	.03	7.0	8.0	3	5	<u>67</u>	<u>45</u>	*.97	.67	<u>85</u>	37	22	25
Morgan	15 m. NW	.01	.03	3.4	2.9	8	5	29	20	<u>1.16</u>	<u>1.17</u>	43	23	28	29
Milnet	23 m. N	.04	.03	7.2	4.8	6	4	33	19	.97	.56	<u>50</u>	18	40	34
Callum	18 m. E	.04	.05	<u>11.0</u>	7.7	9	8	<u>94</u>	37	<u>1.13</u>	<u>1.32</u>	* <u>60</u>	48	49	89
St.Charles	30 m. SE	.04	.05	7.3	6.5	6	8	21	24	-	<u>1.52</u>	31	45	45	108
Sturgeon Falls	48 m. E	.03	.05	5.6	5.6	7	8	23	16	.17	<u>1.05</u>	39	34	72	174
Burwash	17 m. S	.02	.05	3.4	6.7	8	7	27	39	<u>1.15</u>	<u>1.33</u>	44	59	32	69
Nairn Centre	30 m. SW	.05	.03	3.9	4.8	7	7	44	17	.24	.48	<u>52</u>	40	81	64
Penage	23 m. SW	.03	.09	7.2	8.7	9	9	<u>58</u>	<u>82</u>	.14	<u>1.29</u>	<u>79</u>	49	173	50

** Distance and Direction from Sudbury

* Based on one monthly collection

- underlined values are markedly higher than the controls

- Blind River and Mattawa are control plots

Table 6:

Summary of Analysis of Variance (F - values)
For different Chemicals in Vegetation in the Sudbury area
in 1970 and 1971

<u>Chemicals</u>		<u>ToS</u>	<u>As</u>	<u>Co</u>	<u>Cu</u>	<u>Fe</u>	<u>Ni</u>	<u>Zn</u>
<u>Sources of</u>	<u>Year</u>							
<u>Variance</u>								
Species	1970	18.44**	2.33	1.42	8.81**	2.88**	14.28**	46.82**
	1971	12.55**	5.18**	9.96**	9.76**	13.72**	33.25**	94.89**
Stations	1970	14.62**	10.74**	1.09	12.03**	8.62**	10.16**	3.08**
	1971	5.95**	6.95**	0.82	2.01	7.50**	15.78**	4.92*

** Significant at the 1% level

* Significant at the 5% level

Table 7:

The Correlation Coefficient and Regression Equation
of the Air Candle Sulphation Rate and Total Sulphur (%)
in Vegetation Samples

Sudbury 1970 and 1971

Vegetation Sampling Station	Distance and Direction from Sudbury	Average Sulphation Rate mgm SO ₃ /100cm ² /day		Average concentration of Total sulphur (%) in Vegetation	
		<u>1970</u>	<u>1971</u>	<u>1970</u>	<u>1971</u>
Penage	23 miles SW	0.31	0.18	0.18	0.21
Sudbury	Laurn. U.	0.66	0.56	0.24	0.27
Burwash	17 miles S	0.45	0.37	0.26	0.22
Callum	18 miles E	0.55	0.56	0.23	0.31
Skead	16 miles NE	1.63	1.36	0.33	0.43
Rayside	10 miles NW	0.83	0.45	0.23	0.23
Garson	3 miles NE	0.98	1.06	0.40	0.39
Morgan	15 miles NW	0.22	0.14	0.21	0.24
Correlation Coefficient		<u>1970</u> r = 0.73*	<u>1971</u> r = 0.96**	** Significant at 1% level	
Regression Equation		Y = 0.17x + 0.114	Y = 0.18x = 0.18	* Significant at 5% level	

Table 8: Concentrations of the Various Chemical Elements in the Forage (not washed) collected at the Sudbury Special Surveillance Plots in August 1971

<u>Forage</u>	<u>Chemicals</u>				
	ToS %	As ppm	Cu ppm	Fe ppm	Ni ppm
<u>Copper Cliff</u>					
$\frac{1}{2}$ mile north	.57	3.2	43	900	25
1 mile north	.19	3.4	18	190	26
5 miles north	-	2.3	7	132	19
10 miles north	.36	1.2	7	110	12
20 miles north	.14	1.2	3	-	32
1 mile south	.49	2.3	4	65	40
5 miles south	.31	2.8	10	213	26
10 miles south	.39	0.8	4	190	30
25 miles south	.25	-	18	250	37
$\frac{1}{2}$ mile east	.18	2.0	9	113	24
1 mile east	.28	4.3	22	250	-
5 miles east	.51	2.8	11	110	32
10 miles east	.49	3.3	9	164	45
$\frac{1}{2}$ mile west	.38	3.6	91	250	50
1 mile west	.29	4.0	10	236	34
5 miles west	.23	2.3	11	115	4
10 miles west	.26	1.9	2	50	1
25 miles west	.24	1.2	5	75	7
<u>Coniston</u>					
$\frac{1}{2}$ mile north	.32	4.3	35	421	59
1 mile north	.23	-	8	85	16
3 miles north	.49	3.4	11	105	36
$\frac{1}{2}$ mile south	.22	1.0	3	210	18
1 mile south	.35	1.8	3	75	11
5 miles south	.23	1.8	4	95	43
10 miles south	.28	2.3	4	115	24
25 miles south	.21	0.8	5	49	11
$\frac{1}{2}$ mile east	.30	3.6	16	265	48
1 mile east	.51	2.0	18	211	105
5 miles east	.40	1.8	5	195	39
10 miles east	.14	1.8	6	75	23
25 miles east	.19	1.8	5	51	1
<u>Falconbridge</u>					
$\frac{1}{2}$ mile north	.62	7.8	42	580	50
1 mile north	.49	4.6	-	-	-
5 miles north	.33	2.4	3	45	17
10 miles north	.26	2.7	4	45	8
$\frac{1}{2}$ mile south	.33	6.4	13	275	41
1 mile south	.57	4.8	19	360	40
2 miles south	.50	6.4	12	200	39
2 miles southwest	.74	-	24	259	32
5 miles southwest	.40	-	26	401	47
7 miles southwest	.39	-	14	125	43

Table 8 (cont'd): Concentrations of the Various Chemical Elements in Trembling Aspen (washed) collected at the Sudbury Special Surveillance Plots in August 1971

<u>Trembling Aspen</u>		<u>Chemicals</u>			
Location	ToS %	As ppm	Cu ppm	Fe ppm	Ni ppm
<u>Copper Cliff</u>					
2 miles north	.40	3.2	50	450	142
5 miles north	-	2.4	12	500	95
10 miles north	.29	2.0	20	660	66
20 miles north	.41	0.5	8	485	28
1 mile south	.85	-	7	577	80
5 miles south	.37	-	17	169	155
10 miles south	.48	-	11	157	91
25 miles south	.29	-	15	170	6
$\frac{1}{2}$ mile east	.69	6.4	76	1080	84
1 mile east	.50	5.0	26	440	160
5 miles east	.60	3.4	20	270	22
10 miles east	.89	-	70	1650	253
2 miles west	.36	2.4	18	685	76
5 miles west	.24	2.3	14	390	-
10 miles west	.27	1.8	16	125	32
25 miles west	.28	1.9	11	110	11
<u>Conistion</u>					
1 mile north	.52	6.6	37	560	270
2 miles north	.57	6.4	30	400	130
3 miles north	.62	4.8	24	320	74
$\frac{1}{2}$ mile south	.65	8.3	35	520	120
1 mile south	.98	6.6	24	403	160
5 miles south	.39	1.0	8	100	50
10 miles south	.43	2.1	11	365	64
25 miles south	.24	0.8	13	86	36
$\frac{1}{2}$ mile east	.67	5.0	5	52	55
1 mile east	.56	3.2	27	423	105
5 miles east	.40	1.2	12	165	90
10 miles east	.39	2.3	11	108	74
25 miles east	.30	0.5	11	102	11
<u>Falconbridge</u>					
$\frac{1}{2}$ mile north	.53	6.2	27	525	85
1 mile north	.53	6.4	38	565	67
5 miles north	.52	2.4	16	160	62
10 miles north	.45	2.0	12	120	35
1 mile south	.65	5.0	30	460	79
2 miles south	.60	9.3	51	540	170
2 miles southwest	.72	-	27	286	65
5 miles southwest	.59	-	29	509	75
7 miles southwest	.54	-	42	408	202

Table 8(cont'd):

Concentrations of the Various Chemical Elements in the Soil (0-1") collected at the Sudbury Special Surveillance Plots in August 1971

<u>Soil (0-1")</u>			<u>Chemicals</u>		
<u>Location</u>	<u>TgS</u> %	<u>As</u> ppm	<u>Cu</u> ppm	<u>Fe</u> %	<u>Ni</u> ppm
<u>Copper Cliff</u>					
1/2 mile north	.20	-	940	2.13	500
1 mile north	.09	-	220	1.50	120
5 miles north	.02	-	176	1.20	150
10 miles north	.05	-	53	.75	45
20 miles north	.09	-	73	1.23	60
2 miles south	.07	27.2	432	0.70	275
5 miles south	.07	37.0	463	1.14	133
10 miles south	.06	-	85	0.98	50
25 miles south	.01	2.4	10	1.48	25
1/2 mile east	.03	4.0	53	0.95	40
1 mile east	.04	14.8	158	0.95	275
5 miles east	.04	7.2	135	0.95	133
10 miles east	.25	16.6	568	1.23	575
1/2 mile west	.18	-	2600	1.88	2125
1 mile west	.41	-	1007	4.50	1300
5 miles west	.04	-	115	1.09	95
10 miles west	.07	-	91	1.20	100
25 miles west	.02	-	71	1.65	30
<u>Coniston</u>					
1/2 mile north	.21	32.2	443	1.71	500
1 mile north	.16	16.0	375	1.83	293
3 miles north	.12	30.8	193	0.16	178
1/2 mile south	.18	31.6	580	1.80	325
1 mile south	.33	115.0	1025	4.00	625
5 miles south	.10	32.0	318	1.65	188
10 miles south	.04	7.4	53	0.93	63
25 miles south	.04	6.6	48	1.38	33
1/2 mile east	.18	30.6	39	1.75	350
1 mile east	.05	9.2	14	0.83	88
5 miles east	.02	10.2	7	0.83	85
10 miles east	.02	5.4	23	0.88	23
25 miles east	.02	3.4	23	0.93	43
<u>Falconbridge</u>					
1/2 mile north	.22	252.0	405	1.80	295
1 mile north	.22	304.0	580	2.25	370
5 miles north	.04	28.8	138	0.46	115
10 miles north	.02	5.6	57	1.00	55
1/2 mile south	.11	38.0	132	0.89	120
1 mile south	.13	35.6	159	0.33	140
2 miles south	.39	126.0	793	-	700
1/2 mile southwest	.06	30.6	148	0.75	68
1 mile southwest	.06	34.6	-	-	-
5 miles southwest	.06	29.2	193	0.88	100
7 miles southwest	.03	4.6	33	0.45	35

Table 8(cont'd):

Concentrations of the Various Chemical Elements in the Soil (4-6") collected at the Sudbury Special Surveillance Plots in August 1971

<u>Soil (4-6")</u>		<u>Chemicals</u>			
Location	ToS %	As ppm	Cu ppm	Fe %	Ni ppm
<u>Copper Cliff</u>					
1 mile north	.08	-	143	1.54	75
5 miles north	.02	-	35	1.33	38
10 miles north	.03	-	29	-	25
20 miles north	.02	-	15	1.45	15
2 miles south	.01	8.0	63	0.68	98
5 miles south	.01	12.6	88	1.20	50
10 miles south	.06	-	28	1.15	30
25 miles south	.01	3.8	20	1.93	28
1/2 mile east	.01	3.8	10	0.16	8
1 mile east	.02	6.4	58	0.75	58
5 miles east	.02	36.2	35	0.78	55
10 miles east	.12	22.8	508	1.78	215
1/2 mile west	.09	-	1700	1.70	1550
1 mile west	.06	-	120	1.95	190
5 miles west	.02	-	64	1.30	53
10 miles west	.02	-	45	1.11	30
25 miles west	.02	-	47	1.78	60
<u>Coniston</u>					
1/2 mile north	.07	20.6	285	1.28	255
1 mile north	.07	8.0	253	0.75	140
3 miles north	.03	7.4	64	0.26	48
1/2 mile south	.11	22.6	503	1.60	160
5 miles south	.08	9.8	73	1.15	35
10 miles south	.01	5.4	25	1.10	28
25 miles south	.02	4.2	29	1.70	30
1/2 mile east	.04	9.2	21	1.38	100
1 mile east	.03	2.8	32	0.60	25
5 miles east	.03	3.8	8	1.18	33
10 miles east	.02	4.0	13	0.80	20
25 miles east	.01	3.4	5	1.33	13
<u>Falconbridge</u>					
1/2 mile north	.07	234.0	349	1.73	153
1 mile north	.07	54.0	335	1.70	105
5 miles north	.03	4.0	13	1.25	8
10 miles north	.02	0.4	10	1.45	5
1/2 mile south	.03	22.2	67	0.54	43
1 mile south	.09	34.0	145	0.38	105
2 miles south	.03	28.4	34	0.89	88
1/2 mile southwest	.04	8.6	38	0.81	30
1 mile southwest	.06	2.8	28	0.88	25
5 miles southwest	.03	2.4	13	0.83	23
7 miles southwest	.02	2.0	13	0.50	18

Table 9:

Concentrations of the various chemical elements in the snow collected in the Sudbury area in 1972

	ToS (ppm)			Cl (ppm)			Cu (ppm)			Fe (ppm)			Ni (ppm)		
	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.
Blind River	.87	.78	.20	.45	.85	.15	.01	.01	.006	.01	.04	.12	.01	.01	.01
Mattawa	.73	.48	.19	.45	.75	.15	.01	.02	.014	.02	.03	.20	.01	.01	.01
Laurentian U.	1.51	3.33	.67	1.55	7.75	.40	.19	1.25	.13	.04	1.50	.15	.15	.63	.15
Ash Street	1.86	4.33	1.16	7.55	14.35	3.55	1.03	1.63	.46	1.53	1.19	2.81	.69	1.00	.47
New Sudbury	1.90	1.73	.74	3.65	7.75	.65	.52	.49	.13	.86	.53	.85	.46	.28	.11
Cinnottville	6.90	1.70	.28	2.75	4.25	2.65	1.06	.41	.27	1.94	.94	1.71	.56	.18	.13
Naughton	1.16	1.30	.74	1.25	1.75	.95	.10	.17	.15	.09	.28	.56	.04	.05	.06
Lake Penage	.75	.82	.28	1.05	1.70	.65	.04	.03	.03	.05	.12	.40	.01	.01	.03
Nairn	1.00	1.12	.19	1.25	1.15	-	.02	.02	.015	.04	.34	.16	.01	.01	.01
Massey	.94	1.16	.19	.65	3.15	.75	.01	.01	.01	.01	.13	.09	.01	.01	.01
Garson	1.55	1.73	.28	.85	1.95	.55	.26	.44	.12	.45	1.75	1.56	.25	.25	.14
Skead	1.86	3.33	.24	6.15	14.45	.35	.25	.21	.06	.36	2.63	.43	.25	.18	.04
Timagami	.64	.86	-	2.85	4.84	-	.02	.02	-	.02	.13	-	.01	.01	-
Coniston	1.73	1.73	.88	1.45	3.95	1.05	.49	.56	.16	.18	.34	.07	.26	.45	.15
Callum	1.60	1.32	2.08	2.45	1.35	.25	.11	.23	.03	.11	.43	.18	.09	.14	.01
Hagar	1.22	.90	.28	2.45	5.25	.45	.02	.06	.01	.03	.17	.07	.13	.03	.01
Sturgeon F.	.97	.66	.19	1.85	1.75	.10	.01	.03	.01	.02	.21	.05	.01	.01	.01
North Bay (1)	.61	.49	.34	2.75	4.50	.75	.01	.03	.01	.01	.26	.72	.01	.01	.01
North Bay (2)	.70	.97	.22	.50	1.15	.45	.02	.04	.02	.05	.19	.50	.01	.01	.01

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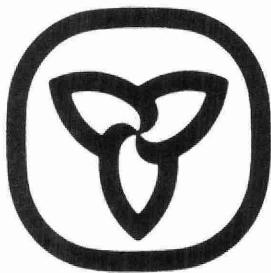
Table 9(cont'd): Concentrations of the various chemical elements in the snow collected in the Sudbury area in 1972

	ToS (ppm)			Cl (ppm)			Cu (ppm)			Fe (ppm)			Ni (ppm)		
	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.	Jan.	Feb.	Apr.
St. Charles	1.73	1.30	.44	.85	8.55	0.15	.01	.18	.02	.03	.31	.14	.01	.09	.01
Happy Valley	1.80	2.06	1.45	.65	3.65	.65	.38	.75	.17	.06	1.00	.04	.51	.40	.20
Hammer	1.18	1.27	.20	24.50	22.5	1.9	.11	.06	.09	.16	.21	1.56	.13	.04	.09
Capreol	1.70	.86	.22	18.65	5.05	.45	.19	.04	.03	.22	.18	.49	.04	.01	.04
Milnet	1.56	.80	.18	1.75	.75	.35	.03	.04	.03	.06	.20	.88	.04	.03	.03
Rayside	1.86	.97	.28	1.85	19.5	1.75	.10	.08	.06	.09	.48	.43	.15	.05	.04
Morgan	1.27	.88	.19	1.25	1.05	.35	.04	.04	.09	.01	.13	1.94	.04	.01	.11
Burwash	.97	1.27	.43	12.45	6.65	1.25	.03	.10	.04	.04	.19	.49	.03	.04	.03
Killarney Rd.	.97	.82	.64	1.45	2.55	.35	.03	.05	.06	.04	.11	.74	.02	.02	.04
Tyson Lake	.82	.97	.22	1.15	1.85	.15	.03	.01	.06	.04	.06	1.20	.03	.01	.09
Killarney Pk.	.46	1.09	.16	3.85	.75	.45	.02	.01	.02	.03	.04	.23	.01	.01	.01

Table 10:

pH of the snow collected in the Sudbury area in 1972

	Jan.	Feb.	Apr.		Jan.	Feb.	Apr.
Blind River	4.6	4.7	4.9	St. Charles	4.6	4.3	4.7
Mattawa	4.2	4.4	-	Happy Valley	4.9	4.5	4.0
Laurentian U.	4.2	4.8	4.8	Hanmer	4.5	4.6	5.5
Ash Street	4.3	4.8	4.8	Capreol	4.4	4.3	5.2
New Sudbury	4.1	4.4	4.7	Milnet	5.0	4.8	5.0
Cinnottville	4.4	4.8	6.0	Rayside	4.4	4.4	4.9
Naughton	4.8	4.4	4.5	Morgan	4.8	4.2	5.3
Lake Penage	4.4	4.3	4.6	Burwash	4.3	4.2	4.7
Nairn	4.3	4.4	4.7	Killarney Rd.	4.7	4.3	4.3
Massey	4.4	4.6	4.8	Tyson Lake	4.2	4.2	4.8
Garson	4.7	4.4	5.0	Killarney Pk.	4.7	4.2	5.1
Skead	4.8	4.3	5.1				
Timagami	4.9	4.8	-				
Coniston	4.5	5.0	4.8				
Callum	4.8	4.3	4.5				
Hagar	4.3	4.1	4.6				
Sturgeon F.	5.0	4.9	4.8				
North Bay (1)	4.8	4.5	4.9				
North Bay (2)	4.6	4.8	4.9				



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